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*Symons, W. R., ... Pottsville, Pa.

*Tasker, Charles P., . . . Morris, Tasker & Co., Limited, Philadelphia.
*Taylor, Charles L., . Pittsburgh Bessemer Steel Co., Limited, Pittsburgh, Pa.
*Taylor, Fred. W., . . . Smithsonian Institution, Washington, D. C.
†Taylor, P. A., ... Pottsville, Pa.
*Taylor, Percyvale, . . . 6 Queen Street Place, London, E. C., England.
*Taylor, W. J., ... Chester, Morris Co., N. J.
*Tefft, Walter, ... Mineville, Essex Co., N. Y.
*Temple, John C., ... Globe Iron Works, Dayton, Ohio.
†Thacher, Arthur, . . . 108 E. Thirty-sixth Street, New York City.
*Thackray, George E., ... Youngstown, Ohio.
*Thaw, William, Jr., ... Pittsburgh, Pa.
*Thies, A., ... Concord, N. C.

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*THOMAS, ALEXANDER, ... Bolton Steel Co., Canton, Ohio.
*THOMAS, D. H., ... Alburtis, Pa.
*THOMAS, EDWIN, ... Catasauqua, Pa.
*THOMAS, JAMES, ... Catasauqua, Pa.
*THOMAS, JOHN, ... Hokendauqua, Pa.
*THOMAS, SAMUEL, ... Catasauqua, Pa.
*THOMAS, SIDNEY G., . . 27 Tedworth Square, Chelsea, London, England.
†THOMAS, W. G., JR., ... Brussels, Calhoun Co., Ill.
*THOMÉ, SAMUEL W., N. E. Corner Fourth and Chestnut Streets, Philadelphia.
*THOMLINSON, WILLIAM, ... West Hartlepool, England.
*THOMPSON, PROF. C. O., ... Worcester, Mass.
*THOMPSON, E. RAY, ... Troy, N. Y.
*THOMPSON, HEBER S., ... Pottsville, Pa.
*THOMPSON, ROBERT M., ... 292 Pearl Street, New York City.
*THOMSON, JOHN L., ... Bergen Point, N. J.
*THONARD, LEON, ... 40 Rue Fusch, Liége, Belgium.
*THURSTON, PROF. R. H., . Stevens Institute of Technology, Hoboken, N. J.
*TILEMANN, J. N., ... Argentine, Kansas.
*TORRANCE, H. C., ... Braddock, Allegheny Co., Pa.
*TORRANCE, J. FRASER, ... Victoria, British Columbia.
*TORREY, HERBERT G., ... U. S. Assay Office, New York City.
*TORRY, DOLPHUS, ... 201 Seventh Avenue, New York City.
*TOUCEY, DONALD B., ... 57 W. Fifty-third Street, New York City.
*TOWER, A., ... Poughkeepsie, N. Y.
*TOWNE, LINWOOD O., ... Rico, Dolores Co., Colorado.
*TOWNSEND, DAVID, ... 1723 Wallace Street, Philadelphia.
*TOWNSEND, HENRY T., ... 218 S. Fourth Street, Philadelphia.
*TRABER, JACOB, ... 2 Public Landing, Cincinnati, Ohio.
*TRENT, L. C., ... Denver, Colorado.
*TROILIUS, MAGNUS, . . . Midvale Steel Works, Nicetown, Philadelphia.
*TROWBRIDGE, PROF. WILLIAM P., . . School of Mines, New York City.
*TUCKER, ALFRED, ... 220 Walnut Street, Philadelphia.
†TUTTLE, H. A., ... Cleveland, Ohio.
*TYLER, ALFRED L., ... Woodstock Iron Co., Anniston, Ala.

*VALENTINE, M. D., ... Woodbridge, N. J.
*VAN ARSDALE, W. H., ... Aurora, Ill.
*VAN BLARCOM, E. C., ... P. O. Box 2085, San Francisco, Cal.
*VAN LENNEP, D., . . Granite Basin, via Buck's Ranch, Plumas Co., Cal.
†VAN TASSEL, HOWARD A., ... Houghton, Mich.
*VAN VOORHIS, W. W., ... Manhattanville, New York City.
*VAN DIEST, P. H., ... 679 California Street, Denver, Colorado.
*VANDLING, A. H., ... Scranton, Pa.
*VANNIER, CHARLES H., ... Succasunna, Morris Co., N. J.
*VEEDER, HERMAN, ... Eddyville, Iowa.
*VEZIN, HENRY A., ... P. O. Box 144, Leadville, Colorado.
*VIVIAN, GEORGE G., ... Freeland, Clear Creek Co., Colorado.
*VULTÉ, HERMANN T., . . . 223 W. Forty-third Street, New York City.

*WAIT, PROF. CHARLES E., ... Rolla, Phelps Co., Missouri.
*WAITE, GEORGE R., ... 119 S. Fourth Street, Philadelphia.

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†WALKER, JOHN A., ... P. O. Box 21, Jersey City, N. J.
†WALKER, N. B., ... 235 Water Street, New York City.
*WALKER, W. R., ... North Chicago Rolling Mill Co., Chicago, Ill.
*WALSH, EDWARD, JR., ... 2721 Pine Street, St. Louis, Mo.
*WARD, WILLARD P., ... Savannah, Ga.
†WARNER, L. E., ... Johnston Buildings, Cincinnati, Ohio.
*WARNER, WILLARD, ... Tecumseh, Cherokee Co., Alabama.
*WARREN, G. HARRY, ... 520 Fifth Avenue, New York City.
*WARREN, H. L. J., ... Crescent City, Del Norte Co., Cal.
*WARTENWEILLER, ALFRED, ... Butte City, Montana.
*WATERMAN, H. L., . . Care of C. H. Odell, 47 Wall Street, New York City.
*WATERS, J. H. E., ... Silverton, Colorado.
*WATTS, DAVID, ... 223 Market Street, Harrisburg, Pa.
†WATTS, ETHELBERT, ... Vesta P. O., Lancaster Co., Pa.
*WEAVER, V. W., ... Coplay, Lehigh Co., Pa.
*WEBB, GEORGE, ... Cambria Iron Co., Johnstown, Pa.
*WEBB, H. WALTER, ... 37 Wall Street, New York City.
*WEEKS, JOSEPH D., ... P. O. Box 1547, Pittsburgh, Pa.
*WEIMER, P. L., ... Lebanon, Pa.
*WEIR, CHARLES G., ... 24 E. Tenth Street, New York City.
*WELLMAN, S. T., ... Otis Iron and Steel Co., Cleveland, Ohio.
*WELLS, BARD, ... Pottsville, Pa.
†WELLS, CALVIN, ... A. French & Co., Pittsburgh, Pa.
*WELLS, H. L., ... South Pueblo, Colorado.
*WENDT, ARTHUR F., ... 414 E. Fifty-first Street, New York City.
*WENTZ, J. S., ... Mauch Chunk, Pa.
*WERNER, AUGUSTIN, ... Mapimi, Durango, Mexico.
*WEST, A. G., ... Cedartown, Polk Co., Ga.
*WESTBROOK, CHARLES R., ... Ogdensburg, St. Lawrence Co., N. Y.
*WHEELER, H. A., ... P. O. Box 1026, New York City.
*WHEELER, MOSES D., ... P. O. Box 231, Stapleton, Staten Island, N. Y.
*WHEELER, WILLIAM D., ... U. S. Assay Office, Helena, Montana.
*WHEELOCK, JEROME, ... Worcester, Mass.
*WHINERY, S., ... Meridian, Miss.
*WHITE, WILLIAM, JR., ... Braddock, Allegheny Co., Pa.
*WHITING, S. B., ... Pottsville, Pa.
†WHITNEY, ELI, JR., . . . Whitneyville Armory, New Haven, Conn.
†WICKERSHAM, J. M. K., ... 308 Branch Street. Philadelphia.
*WIESTLING, GEORGE B., ... Mont Alto, Franklin Co., Pa.
*WIGHT, SIDNEY B., ... 403 Jefferson Avenue, Detroit, Mich.
*WILES, EDWIN L., ... Springfield Iron Co., Springfield, Ill.
*WILEY, WILLIAM H., ... 15 Astor Place, New York City.
*WILHELM, A., ... P. O. Box 178, Harrisburg, Pa.
*WILHELM, J. SCHALL, ... Cornwall, Lebanon Co., Pa.
*WILLARD, H. B., ... Port Henry, Essex Co., N. Y.
*WILLIAMS, ALBERT, JR., ... Box 591, Washington, D. C.
*WILLIAMS, BEN, ... Bisbee, Arizona.
*WILLIAMS, DAVID, ... 83 Reade Street, New York City.
*WILLIAMS, D. H., ... Homestead, Allegheny Co., Pa.
*WILLIAMS, PROF. EDWARD H., JR., . . . P. O. Box 463, Bethlehem, Pa.
*WILLIAMS, FREDERICK H., ... S. St. Louis, Mo.

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*Williams, Henry, ... Butte City, Montana.
*Williams, John R., ... Pittsburgh, Pa.
*Williams, John T., . Forty-fourth Street and East River, New York City.
*Williams, Samuel T., ... Albany Iron Works, Troy, N. Y.
*Williams, W. E., ... Springfield Iron Co., Springfield, Ill.
†Williamson, G. N., ... Irwin, Gunnison Co., Colorado.
*Wills, L. E., ... Weissport, Carbon Co., Pa.
†Wilson, Henry C., ... U. S. Engineer Office, Memphis, Tenn.
*Wilson, John A., ... 435 Chestnut Street, Philadelphia.
*Wilson, John T., ... Wilson, Walker & Co., Pittsburgh, Pa.
*Wilson, Joseph M., ... Otis Iron and Steel Co., Cleveland, Ohio.
*Wilson, N. R., ... P. O. Box 1609, Leadville, Colorado.
*Winslow, Arthur, ... 907 Walnut Street, Philadelphia.
†Wishon, Walter W., ... Colorado Springs, Colorado.
*Wister, Jones, ... Harrisburg, Pa.
*Witherbee, Frank S., ... Port Henry, Essex Co., N. Y.
†Witherbee, S. H., ... 228 Madison Avenue, New York City.
*Witherbee, T. F., ... Port Henry, Essex Co., N. Y.
*Witherbee, W. C., ... P. O. Box 275, Newport, R. I.
*Witherow, J. P., . . . Market and Water Streets, Pittsburgh, Pa.
*Witherspoon, James, ... Pearisburg, Giles Co., Va.
†Wittmack, Charles A., ... Strasburg, Germany.
†Wolcott, Henry R., ... Denver, Colorado.
*Wolf, Theodore G., ... Scranton, Pa.
*Wolfe, Albert H., ... P. O. Box 3177, New York City.
*Wolff, Dr. Fr. M., . . . German Consulate General, New York City.
*Wood, A. B., ... Ann Arbor, Mich.
*Wood, Edward L., ... 2716 Carson Street, Pittsburgh, Pa.
*Wood, Frederick W., ... Steelton, Dauphin Co., Pa.
*Wood, Thomas D., ... McKeesport, Pa.
*Wood, W. J., ... Collinsville, Conn.
*Woodbury, L. S., ... Calumet, Mich.
*Woodward, E. H., ... 54 Cliff Street, New York City.
*Woodward, Richard W., ... South Pueblo, Colorado.
*Wright, Charles E., ... Marquette, Mich.
†Wright, Harrison, ... Wilkes-Barre, Pa.
*Wright, James N., ... Calumet, Mich.
*Wright, J. Whitaker, . . . Third and Walnut Streets, Philadelphia.
*Wurts, Charles P., ... New Haven, Conn.

*Young, James B., ... Phœnix Roll Works, Pittsburgh, Pa.
†Young, Rev. Jesse B., ... Altoona, Pa.

Honorary Members, 5; Members, 1009; Associates, 149; Foreign Members, 50.

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Deceased.

Blossom, T. M.,	1876
Briggs, Robert,	1882
Brown, A. J.,	1875
Caldwell, W. B., Jr.,	1880
Cameron, James R.,	1881
Chisholm, Henry,	1881
Clark, Henry G.,	1881
Clemes, J. P.,	1876
Daddow, S. H.,	1875
D'Aligny, H. F. Q.,	1875
Dresser, Charles A.,	1878
Dwight, W. S.,	1883
Firmstone, William,	1877
Fuller, John T.,	1880
Gould, Robert A.,	1878
Harris, Stephen,	1874
Healy, Morris,	1881
Holley, A. L.,	1882
Hunt, Thomas,	1872
Jenney, F. B.,	1876
Jernegan, J. L.,	1881
Lee, Washington,	1872
Liebenau, Charles von,	1875
Lord, John C.,	1872
Lorenz, W., Jr.,	1881
McIntire, Henry M.,	1880
MacMartin, Archibald,	1881
Mickley, J. W.,	1880
Moore, Charles W.,	1877
Newton, Henry,	1877
Painter, Howard,	1876
Phelps, Walter,	1878
Pleasants, Henry,	1880
Richter, C. E.,	1877
Robinson, Thomas W.,	1880
Schirmer, J. F. L.,	1877
Steitz, Augustus,	1876
St. John, I. M.,	1880
Stoelting, Hermann,	1875
Thomas, David,	1882
Walz, Isidor,	1877
Welch, Ashbel,	1882
Wendel, Dr. A.,	1881
Wheatley, Charles M.,	1882
Whilldin, W. I.,	1882
Wickes, George T.,	1882
Witherbee, J. G.,	1875
Worthington, Henry R.,	1880
Wrigley, H. E.,	1882

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RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1889, and FEBRUARY, 1881.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versa*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote or to be members of the Council.

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Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; *Provided*, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meet-

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ings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of the majority of the members then present. The place of meeting shall be fixed in advance by the Institute, or, in default of such determination, by the Council, and notice of all

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meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds' vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

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PROCEEDINGS.

OF THE

VIRGINIA MEETING.

MAY, 1881.

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COMMITTEE OF ARRANGEMENTS.

General Committee.—J. F. Lewis, Quinnimont, W. Va.

Committee of Reception at Staunton.—Major Jed. Hotchkiss, Chairman; W. A. Burke, M. E. Miller, R. N. Catlett, W. J. Nelson, J. T. Effinger, D. A. Kayser.

Local Committee of Arrangements.—G. T. Wickes, Low Moor, Chairman; G. W. Bramwell, Stone Cliff, Secretary; J. E. Johnson, Longdale; H. Firmstone, Longdale; S. F. Morris, Quinnimont; C. A. Rundall, Ferrol; William N. Page, Ansted; F. Lyman, Low Moor; S. M. Buck, Coalburgh; E. S. Hutchinson, Cannelton; M. F. Maury, Saltpetre Cave.

THE opening session of the Institute was held at Staunton, on Monday evening, May 30th, in the Opera House. Major Jed. Hotchkiss, Chairman of the Committee of Reception, called the meeting to order and introduced Mayor Balthis, who spoke a few words of welcome to the members present, and then introduced the Hon. A. H. H. Stuart.

Mr. Stuart in addressing a formal welcome to the Institute to the "little city of the mountains," spoke of the value of the services of the mining engineer in developing the mineral wealth of Virginia and in solving the problems of her geological history.

Mr. Metcalf, President of the Institute, replied on behalf of the Institute to the cordial welcome of the mayor and Mr. Stuart, and then read an inaugural address on Force.

At the conclusion of the President's address the following papers were read:

The Electrolytic Determination of Copper and the Formation and Composition of so-called Allotropic Copper, by J. B. Mackintosh, Hoboken, N. J. Read by Professor Egleston.

The New Unpublished Map of Chester County, Pa., by Professor Persifor Frazer, Philadelphia.

The second session was held at the Opera House on Tuesday morning. The papers read at this session were:

Investigations on the Ore Knob Copper Process, by Professor Thomas Egleston, School of Mines, New York city.

A Volumetric Estimation of Manganese in Pig Iron and Steel, by F. H. Williams, Vulcan Steel Works, St. Louis, Mo. Read by the Secretary.

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Manganese Determinations in Steel, by William Kent, of Pittsburgh, Pa. Read by the Secretary.

The discussion of the subject of steel rails, begun at the Philadelphia meeting, was then resumed. Communications from Professor Rich. Akerman, of Stockholm, Sweden, and C. P. Sandberg, of London, were read, and Dr. R. W. Raymond and Dr. C. B. Dudley took part in the discussion.

The third session was held in the rooms of the Young Men's Christian Association on Tuesday afternoon. The papers read were:

Black-band Iron Ore in West Virginia, by S. P. Sharples, Boston.

The Rich Hill Iron Ores and the Falling Cliff Zinc Mine, by F. P. Dewey, Chattanooga, Tenn.

Gerstenhöfer's Ammonia-Soda Process, by O. J. Heinrich, Drifton, Pa.

Notes on the Hard Splint Coal of the Kanawha Valley, by Stuart M. Buck, Coalburgh, W. Va.

The fourth session was held on Thursday evening in the Masonic Hall.

Professor Frazer read a paper on Some Ores of the Middle James River, after which Major Hotchkiss gave a description of the topographical features of the Shenandoah Valley, with especial reference to the trip to Luray on the following day.

A brilliant reception tendered by the citizens and ladies of Staunton, to the visiting members and their ladies, took place after the session on Tuesday evening, at the Deaf, Dumb, and Blind Institution, the halls of which were tastefully decorated with flags and mottoes, and the extensive grounds brilliantly illuminated. Music by the Stonewall Jackson Band enlivened the occasion, which concluded with supper, prepared under the supervision of the ladies of Staunton.

The fifth and concluding session was held in the ballroom of the hotel at the White Sulphur Springs, West Virginia, on Thursday evening, June 2d.

Owing to the fatigue of the members from the excursion of the day, and the lateness of the hour, the remaining papers on the list were read by title:

The Hydrometallurgy of Copper and its Separation from the Precious Metals, by Dr. T. Sterry Hunt, Montreal, Canada.

The Foreign Substances in Iron and their Combinations, by F. L. Kleinschmidt, St. Louis, Mo.

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Notes on Gold Mill Construction, by A. J. Bowie, Jr., San Francisco, Cal.

Index to American Engineering Articles and Papers, for 1880, by Professor H. S. Munroe, New York city.

The New Westmoreland Shaft, by W. P. Little and T. B. Stearns, New York city.

Filtering in Industrial Operations, by P. Barnes, Springfield, Ill.

On the Solution of Pig Iron and Steel for the Determination of Phosphorus, by N. H. Muhlenberg and T. M. Drown, Easton, Pa.

Blast Furnace Hearths and Linings, by John Birkinbine, Philadelphia.

An Improved Mining Lamp, by Professor P. Frazer, Philadelphia.

An Analysis of the Casualties in the Anthracite Coal Mines from 1871 to 1880, by Dr. H. M. Chance, Philadelphia.

The following persons, duly proposed and recommended by the Council, were unanimously elected members and associates of the Institute.

MEMBERS.

H. G. Blackwell,	Rocky Mount, Va.
William M. Bowron,	Shenandoah Iron Works, Va.
Robert Briggs,	Philadelphia, Pa.
George M. Brinkerhoff,	Springfield, Ill.
Charles Brock,	Manhattanville, New York City.
George Brooke,	Birdsboro', Pa.
Edward L. Brown,	New York City.
J. Stuart Brown,	Pittsburgh, Pa.
William H. Brown,	Philadelphia.
A. J. Charleton,	Marmora, Canada.
Verplanck Colvin,	Albany, N. Y.
Ralph Crooker, 3d,	South Pueblo, Colo.
George B. Cummings,	Marquette, Mich.
William J. Donaldson,	Philadelphia, Pa.
Alfred Earnshaw,	Philadelphia, Pa.
William H. Hackett,	Cartersville, Ga.
Maurice Healy,	Dunbar, Pa.
Edward R. Howe,	Leadville, Colo.
William Irving,	Chicago, Ill.
Walter N. Johnson,	Buchanan, Va.
William Jolliffe,	Buchanan, Va.
John Kean, Jr.,	Elizabeth, N. J.
Frank King,	Van Buren Furnace, Va.
F. L. Kleinschmidt,	St. Louis, Mo.
J. King McLanahan,	Hollidaysburg, Pa.

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R. L. Martin,	Fairchance, Pa.
S. Price Maury,	Richmond, Va.
John W. Maxwell,	Syracuse, N. Y.
Horace B. Miller,	New York City.
E. D. Peters, Jr.,	Copperas Hill, Vt.
F. Prince,	Audenried, Pa.
J. Wesley Pullman,	Philadelphia, Pa.
James Reed,	Altoona, Pa.
John W. Smith,	Syracuse, N. Y.
W. Dwight Smith,	Trenton, N. J.
N. Allen Stockton,	Riverville, Va.
Alexander Strausz,	Raccoon, W. Va.
H. A. Strode,	Amherst Court-house, Va.
Myron H. Strong,	Yonkers, N. Y.
Percyvale Taylor,	Bristol, England.
William Thomlinson,	South Pittsburg, Tenn.
Linwood O. Towne,	Newtonville, Mass.
William H. Wiley,	New York City.
H. L. Wells,	South Pueblo, Colo.
Charles P. Wurts,	New Haven, Conn.

ASSOCIATES.

George Auchy,	Pottstown, Pa.
Philip E. Chazal,	Atlanta, Ga.
Thomas P. Conant,	Copper Falls, Mich.
Thomas Dunlap,	Amherst Court-house, Va.
E. Burd Grubb,	Beverly, N. J.
Charles C. Hewitt,	Trenton, N. J.
Cooper Hewitt,	New York City.
Willard P. Little,	New York City.
Joseph S. Ludlam,	Lowell, Mass.
N. H. Muhlenberg,	Reading, Pa.
E. A. Oothout,	New York City.
Clarence Q. Payne,	Stamford, Conn.
Ferdinand Sands,	New York City.
William A. Shumway,	New York City.
Thomas B. Stearns,	Brooklyn, N. Y.
Donald B. Toucey,	New York City.
Howard A. Van Tassel,	Houghton, Mich.
W. George Waring,	Denver, Colo.
Ethelbert Watts,	Verta, Pa.

The status of Mr. John Markle, of Jeddo, Pa., was changed from associate to member.

Professor Persifor Frazer made a statement with regard to a collection of specimens connected with the New York obelisk, which had been presented to the Institute by Lieutenant-Commander Gorringe, and offered the following resolution, which was unanimously adopted:

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Resolved, That the Institute offers its sincere thanks to Lieutenant-Commander Henry H. Gorringe, United States Navy, for the gift to the Institute of the very interesting series of objects connected with the obelisk recently placed by him in the Central Park, New York City, and that the Secretary be instructed to convey to Lieutenant-Commander Gorringe the assurance that this gift is highly appreciated, and that the objects will be watchfully cared for.

A resolution was then offered expressing the thanks of the members for the courtesies and hospitality received from the Shenandoah Valley, the Chesapeake and Ohio, and the Richmond and Allegheny railroads, to the citizens and ladies of Staunton, the Low Moor Iron Company, the Longdale Iron Company, the Ansted Coal Company, the Pennsylvania and Virginia Iron and Coal Company, and to Messrs. Lewis, Hotchkiss, and Wickes, and their associates on the Committee of Arrangements. The meeting was then declared adjourned.

EXCURSIONS.

On Wednesday morning, June 1st, a trip was made by special train, provided by the Shenandoah Valley Railroad, to Luray Cave, which, by the courtesy of the railroad company, was brilliantly illuminated with thousands of candles. After a visit of several hours in the cave, the party returned to Staunton. On the way to Luray a stop was made at the Shenandoah Iron Works, where iron blooms are made from pig iron by means of the run-out fire and charcoal forges.

The Chesapeake and Ohio Railway kindly offered the Institute a special train over its road for three days. On Thursday morning the party leaving Staunton started westward on its tour of inspection. The Grace Furnace of the Pennsylvania and Virginia Coal and Iron Company, at Ferrol, was first visited. The next stop was at the junction of the narrow gauge road of the Longdale Iron Company (Messrs. Firmstone, Pardee & Co.), on which the party was carried seven miles to the furnaces, where the ladies alighted to enjoy the hospitality of Mrs. J. E. Johnson, and thence four and a half miles to the ore banks, under the guidance of Messrs. H. Firmstone and J. E. Johnson. On returning, a short time was allowed for inspection of the furnaces and machinery. The works and mines of the Low Moor Iron Company, Mr. George T. Wickes, Manager, were next visited, and the party was here charmingly entertained at dinner by Mr. and Mrs. Wickes. Early in the evening the train reached White Sulphur Springs, where the large hotel was opened for the reception of the members of the Institute, in advance of the regular season, by Colonel George L. Peyton.

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An early start was made on Friday morning for a visit through the the picturesque cañon of the New River to the coal fields at Hawk's Nest, and thence to Coalburgh, on the Kanawha. Stops were made at Quinnimont, where the Pennsylvania and Virginia Coal and Iron Company has a coke furnace, under the management of Mr. J. F. Lewis, and at the coal mines and coking ovens at Stone Cliff, Fire Creek, Sewall, Nuttallburgh. At Hawk's Nest the party were taken in coal cars on a narrow gauge road to the coal mines, a distance of four miles, up a picturesque gorge. Lunch was here served in a grove, which added an additional pleasure to the charming incidents of the day. The lateness of the hour did not allow of the inspection of Mr. S. M. Buck's work at Coalburgh, and the train after reaching this point returned to White Sulphur Springs.

On Saturday a trip was made to the Natural Bridge. The journey was over the Chesapeake and Ohio Railway to Williamson's, and thence over the new Richmond and Allegheny Railroad to a station a few miles distant from the bridge, where carriages were in waiting. After an hour or two had been devoted to inspecting the bridge, and the party had dined as guests of the railroad company, Colonel H. C. Parsons, by request, gave an account of the construction of the R. & A. R. R., the country it was intended to develop, and the connections which would ultimately be effected. Vice-President Frazer responded on behalf of the Institute and expressed the thanks of the members present for the kind reception and generous hospitality that had been extended to them. A delightful series of excursions was thus concluded and the party broke up, some going East and others returning to White Sulphur Springs to spend Sunday.

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PAPERS

OF THE

VIRGINIA MEETING.

MAY, 1881.

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THE HYDROMETALLURGY OF COPPER, AND ITS SEPARATION FROM THE PRECIOUS METALS.

BY T. STERRY HUNT, LL.D., F.R.S., MONTREAL, CANADA.

WET processes for the extraction of copper from its ores have of late attracted much attention, especially in Europe, where the use of cupriferous iron-pyrites as a source of sulphur prevails. These processes present an additional interest, when, as is often the case, the copper-ores to be treated contain one or both of the precious metals, since the complete separation of these from copper, either in the dry or the moist way, is, as is well known, one of the difficult problems of metallurgy. The principal wet processes hitherto in use for the extraction of copper from its ores may be included under three classes:

I. Those in which the copper in sulphuretted ores is rendered soluble in water by calcining them, after a preliminary roasting which removes the greater part of their sulphur, with a portion of common salt, by which the copper is converted into a chloride (Longmaid and Henderson), or with sulphate of soda, by which sulphate of copper is formed (Monnier). Allied to these is the method by which a portion of the copper is got as soluble sulphate by roasting without addition, a process which is sometimes modified and rendered more complete by re-roasting the lixiviated residues with the addition of a portion of raw sulphuretted ore (Bankart).

II. Those methods in which free chlorhydric or sulphuric acid is used to dissolve the copper from oxidized or roasted ores. These, while simple and efficient, are too costly, except in certain localities where chlorhydric acid is a waste product. Related to them is the plan which consists in exposing the oxidized and moistened ores to the slow action of sulphurous acid mixed with air, by which a soluble sulphate of copper is formed. It has been proposed to decompose the solutions of sulphate or chloride of copper by sulphuretted hydrogen, thus separating the copper as sulphide, and using the liberated acid to dissolve fresh portions of oxidized copper. It is, however, the almost universal practice to throw down the copper from its solutions, however obtained, in the metallic state by the use of iron, either scrap-iron or iron-sponge; although in some instances

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milk of lime has been used as a precipitant, by which oxide of copper is produced.

III. The method in which a hot solution of ferrous chloride, with common salt, is used to chloridize the oxidized copper and convert it into a mixture of cupric and cuprous chlorides, which latter, though nearly insoluble in water, is dissolved by help of the chloride of sodium. From this solution the copper is precipitated by metallic iron, thereby reproducing the ferrous chloride, and regenerating the solvent, an advantage which this process possesses over any other that gives the copper in the metallic form. This, which is known as the Hunt and Douglas method, may, in many cases, be used with advantage for the treatment of low-grade copper ores, and, as the neutral solvent does not dissolve either arsenic or antimony, enables fine copper to be got directly from ores holding these impurities.*

When, however, it is applied to the treatment of copper-ores containing silver, the use of the bath of ferrous chloride and chloride of sodium has, in common with the method of roasting with salt, the disadvantage that it converts the silver into a chloride which is soluble in a strong solution of chloride of sodium and is then with difficulty separated from the chlorides of copper. The separation of silver and copper, when dissolved together in the state of chlorides, has greatly exercised the ingenuity of metallurgical chemists from its importance in connection with the treatment of Spanish and Portuguese pyrites, now so extensively used in Great Britain as a source of sulphur, where the consumption in 1877 amounted to 600,000 tons. These ores contain on an average about forty-nine per cent. of sulphur and two or three per cent. of copper, with a little silver, equal, according to Claudet, to from twenty to twenty-eight grams to the ton of ore, and traces of gold. The residues after calcination still retain three or four per cent. of sulphur and about four per cent. of copper, with sixty per cent. or more of iron, chiefly as peroxide. This material, after having been again calcined for some hours at a low heat in a reverberatory with about fifteen per cent. of common salt (or, as at Oker in Germany, with crude chloride of potassium), gives up to water acidulated with a little chlorhydric

* The hydrous silicate of copper (chrysocolla) is, like the carbonates of copper, completely decomposed by a hot solution of ferrous chloride with common salt. An account of the application of this method to the treatment of a crystalline hydrous silicate of alumina, magnesia, and copper (which is essentially a copper-chlorite, and has been described by the writer as a new species under the name of venerite), will be found in the Transactions of the American Institute of Mining Engineers, vol. iv, p. 328.

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acid its sulphur as sulphate of soda, and its copper and silver as chlorides, together with a considerable excess of common salt, leaving behind a nearly pure peroxide of iron with not over two thousandths of copper. A minute portion of gold, which was converted into aurous chloride during the roasting, is also present in the solution.* The lixivium, in an example given by Claudet, had a specific gravity of 1.24, and held in a meter-cube, besides 144.0 kilograms of sulphate of soda, 64.0 of chloride of sodium, and 52.8 of copper, as protochloride, besides small portions of zinc and iron, with a little lead, and 44 grams of silver. The above details of the salt-roasting process, which have often been published, are here repeated in order to bring more clearly before us the problem of separating the silver from the copper.

Various plans have been suggested for extracting from such solutions as the above the dissolved silver before throwing down the copper by metallic iron. It has been proposed to precipitate the silver by finely-divided metallic copper, as is done in the Augustin process from solutions of chloride of sodium holding only dissolved silver-chloride; but, since metallic copper at once converts protochloride into dichloride of copper, it becomes necessary, as a preliminary to the precipitation of the silver by this means, that the whole of the copper in the solution should first be brought into the latter condition. This may be effected by treating the hot solution with sulphurous acid, or by filtering it, at a temperature near the boiling-point, through a layer of coarsely-ground copper matte, or of vitreous or purple copper ore, from which, as I have found, a second equivalent of copper is taken up. From solutions holding the whole of the copper as dichloride, the silver may be readily thrown down in the metallic state by filtering them through a layer of finely-divided metallic copper; but, inasmuch as the dichloride requires to hold it in solution, a great volume of hot concentrated brine,† this method

* Plattner, as is well known, showed that gold, like silver, is chloridized when pyritous ores containing it are roasted at a low red heat with common salt; an aurous chloride being apparently found, which, in the presence of chloride of sodium, has a considerable degree of stability, though it is decomposed at higher temperatures. This chloride of gold is insoluble in water, and, unlike chloride of silver, is not decomposed by mercury. It is but slightly soluble in brine, though readily dissolved by a solution of hyposulphite of soda or lime. A process proposed by Kiss for the simultaneous extraction of silver and gold from pyritous ores is based on these reactions.

† 100 cc. of a solution holding 15.0 grams of chloride of sodium, dissolve at 90° C., 10.0 grams; at 40°, 6.0 grams; and at 14°, 3 5 grams of cuprous chloride; while 100 cc. of a solution holding 5.0 grams of chloride of sodium, dissolve at 90°

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of separating silver from solutions containing a considerable amount of copper is not in all cases practicable.

Among the plans which have been proposed for the separation of the silver from these saline solutions are those based on fractional precipitation. This is effected, as at Oker, by the use of sulphide of sodium; or better, by diluted sulphuretted hydrogen gas, as got by the action of air mixed with carbonic acid on the waste calcium-sulphide from Leblanc's soda-process. In the latter case, the whole of the silver is, according to Gibbs, carried down with the first six per cent. of the copper. Snelus blows finely-divided metallic iron into the solution, and finds the first twenty per cent. of copper thus precipitated holds four-fifths of the silver. For the extraction of the silver from the mixed sulphides it suffices to convert the silver into a sulphate, as in the Ziervogel process. For the separation of silver from precipitated copper, J. A. Phillips, by a process patented in 1877, makes the material into a paste with water and a mixture of common salt and carbonate of soda; and, after calcination in a reverberatory, gets the silver in the form of chloride, which is dissolved out by brine from the oxidized copper.

The solvent power of solutions of chloride of sodium for chloride of silver is diminished by dilution, and upon this fact, apparently, is based a process for the separation of silver, patented in 1877 in Great Britain by Jardine & Chadwick, which consists in diluting the strong lixivium from the salt-roasted ore to about specific gravity 1.10—1.12, and adding thereto, in the form of a dilute solution, about half a pound of acetate of lead to the ton of liquid. The precipitate, which after a time separates, consisting, in large part, of sulphate of lead, carries with it a portion of chloride of silver, and, it is said, a trace of gold.

The most elegant method for the separation of silver from these mixed solutions is, however, that patented by Claudet, and extensively applied in Great Britain. It depends on the almost complete insolubility of iodide of silver in solutions of chloride of sodium, and consists in adding to the lixivium, in which the proportion of dissolved silver has previously been determined, a dilute solution of a

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2.6 grams, and at 40°, 1.4 grams of cuprous chloride. This substance, contrary to the received statements, is not quite insoluble in water When the cuprous chloride is boiled with distilled water an amount equal to about 1.35 grams to a liter passes into solution, and is in part thrown down on cooling in a white crystalline form; the solution, at 14° C., still retaining about 0.90 grams to the liter. The above numbers are only approximations.

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soluble iodide just sufficient in amount to convert the whole of the silver into iodide of silver. The precipitate, which separates after forty-eight hours of repose, is washed with dilute chlorhydric acid to remove adherent copper-salts, and then consists chiefly of a mixture of sulphate of lead with iodide of silver, which is reduced by metallic zinc, the iodine being thus recovered for further use. Treated in this manner, the calcined Spanish ores yield for each ton 20 grams of silver containing 1.3 per cent. of gold, amounting, according to Lunge, to about two-thirds the entire amount of precious metals contained in the ore. The presence of dichloride of copper in the solution interferes, by the production of a cuprous iodide, with the separation of the silver as iodide; and hence the calcination of the ores with salt must be so conducted as to give the copper in the condition of protochloride.*

The extraction of copper from its ores by roasting with salt is limited to pyritous ores poor in copper, which yield, by their previous calcination, a large proportion of peroxide of iron; the presence of this being necessary to the effectual chloridizing of the copper in the furnace. When applied to richer ores this method fails to render the whole of the copper soluble, for reasons which are made apparent by the investigations of Mr. Thomas Macfarlane, described by him in 1865. He found that while copper-ores, such as chalcopyrite and bornite, when calcined with salt, either alone or with an admixture of pulverized quartz, yield but a small portion of their copper in the form of soluble chloride, such a mixture of ore and salt, with twice its weight of peroxide of iron, and a little pyrites to furnish additional sulphur, if calcined at a low temperature, and without stirring, gave up nearly all its copper to water as a soluble chloride. It was made evident, from these and other experiments described by Macfarlane, that the mass of heated peroxide of iron, in the presence of air, favors the conversion of the sulphur into a sulphate, through which the decomposition of the common salt and the chloridizing of the copper is effected.†

These conditions are most fully realized when a material like the calcined residue of Spanish pyrites, containing in 100 parts about 4 parts each of copper and sulphur, and 80 parts or more of peroxide of iron, is calcined with a sufficient amount of common salt, in which

* For an excellent account of wet processes for the extraction of copper, see Friedr. Bode, in Dingler's Polytechnisches Journal for January–March, 1877, vol. ccxxxi, pp. 254, 357, 428.

† Canadian Naturalist, second series, vol. ii, pp. 219–231, and vol. iii, p. 457.

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case, as we have seen, the chloridizing of the copper is nearly complete. Ignorance of these conditions has more than once led to failure in attempts to apply this process of copper-extraction.

Unlike the method of chloridizing by roasting with salt, that depending on the use of a solution of ferrous chloride with salt is a general one, applicable to all naturally or artificially oxidized copper-ores, which may be readily and cheaply chloridized by its aid.* When applied to copper ores containing silver, however, this shares with the salt-roasting process the disadvantage that the silver is at the same time chloridized, and if not present in too large an amount, is dissolved, while the dichloride of copper, formed by the reaction between the oxide of copper and the ferrous chloride, precludes the use of Claudet's method of precipitating the dissolved silver by a soluble iodide.

There is a large class of copper-bearing ores and furnace-products containing, besides silver, and in some cases gold, portions of antimony and arsenic, often accompanied by lead, the treatment of which, either by the wet or the dry way, offers many difficulties. A simple and economical general method, which will effect a complete separation of copper from silver and gold on the one hand, and from arsenic, antimony, and lead on the other, has hitherto been a desideratum in metallurgy. From the want of such a process considerable quantities of refined copper extracted from Western ores and mattes, and carrying from 40 to 50 ounces of silver per ton, have of late years been sold in our markets.

With my friend, Mr. James Douglas, Jr., of Phœnixville, Pa., I have devoted much time to the metallurgical problem thus presented, and as the result of our joint labors have now to bring before the Institute of Mining Engineers a novel wet process for the extraction of copper from its ores, which will, I think, be found to meet the required conditions. The new method is based upon the reaction described by Wöhler between sulphurous acid and a solution of protochloride of copper, which gives rise to insoluble dichloride with the elimination of one-half the chlorine in the form of chlorhydric acid, and the simultaneous formation of sulphuric acid, as simply expressed in the old notation by the formula,

$$2CuCl + SO_2 + HO = Cu_2Cl + HCl + SO_3.$$

The resulting acid solution, when brought in contact with cupric

* A process of copper-extraction, based on this principle, is the subject of United States letters-patent, granted to T. Sterry Hunt and James Douglas, Jr., February 9th, 1869.

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oxide, will take up as much copper as it originally held, which may, in its turn, be thrown down by sulphurous acid. In this way, the solution of copper from an oxidized ore, and its precipitation as dichloride, may be repeated indefinitely, provided chlorine be supplied each time by the addition of a sufficient amount of some soluble chloride.

The reaction between sulphurous acid and a solution of protochloride of copper goes on slowly at ordinary temperatures, but is very rapid between 80° and 90° C. Solutions of sulphate of copper mixed with an equivalent of chloride of sodium, and holding 8.0 per cent. of copper, after being treated at 90° C. with an excess of sulphurous-acid gas, retain less 1.0 per cent. of dissolved copper; while in the presence of an excess of sulphate of copper and sulphurous acid the precipitation of the chlorine from chloride of sodium is nearly complete; sulphate of soda and sulphuric acid remaining in solution in accordance with the equation

$$2CuO,SO_3 + NaCl + SO_2 = Cu_2Cl + NaO,SO_3 + 2SO_3$$

The sulphurous-acid gas for effecting this reaction on a large scale is readily got in sufficient purity from the burning of iron-pyrites in the ordinary kilns used by the makers of sulphuric acid, care being taken that an excess of air be avoided. A Knowles pump, constructed for the purpose, has proved an efficient means of injecting the heated gas into the liquid. By this reaction we have found it easy, in repeated trials with a small experimental plant, to throw down in three hours' time 125 pounds of copper from an eight per cent. solution, the liquid still retaining about one per cent. of copper dissolved.

The acid liquors, when the reaction with sulphurous acid is complete, have exchanged their bright blue color for a pale green, and now contain in solution an excess of sulphurous acid, which must be got rid of before using them to dissolve a fresh portion of copper. This may be effected by keeping back a small portion of the chloridized copper-solution, and after the action of the gas is complete, as may be known by the changed color and the sulphurous odor of the liquid, adding the reserved portion thereto, by which means the excess of sulphurous acid will be oxidized. The chief part of the dichloride of copper separates during the passage of the gas, but a further portion is deposited on the cooling of the solution.

The excess of sulphurous acid may also be got rid of by blowing a current of hot air through the liquid after it has been withdrawn from the precipitated dichloride, and best while the process of sat-

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urating it with oxide of copper is going on. This, when got by the calcination of sulphuretted ores, contains more or less suboxide of copper,* which, with chlorhydric acid forms a portion of cuprous chloride, and the separation of this, under these circumstances, may be prevented by the action of atmospheric oxygen.

Cuprous chloride is quickly transformed into cupric oxychloride by atmospheric oxygen, and when dissolved or suspended in an acid liquid is by this means readily converted into a cupric salt, which may be again reduced to cuprous chloride by the action of sulphurous acid. In this way, like the nitric oxide in the leaden chamber, the cuprous chloride acts as a medium through which sulphurous acid and oxygen are made to combine and to form sulphuric acid. The two reactions of oxidation and reduction just described may go on alternately or simultaneously in the liquid, and thus it happens that when an excess of air enters the pyrites-kiln, so that considerable free oxygen passes with the sulphurous acid into the copper-solution, the dichloride is either separated slowly or not at all, while at the same time much sulphuric acid is formed. By taking advantage of these reactions between oxygen, sulphurous acid, and chloride of copper, we may at will increase the solvent power of our acid bath.

In applying this new process of copper-extraction to a roasted sulphuretted ore or matte, which we will suppose to contain a portion of silver, we begin by dissolving therefrom by water the sulphate, which, with proper care in roasting, should contain not less than one-third of the copper of the ore; taking care to add to the water enough of some soluble chloride to chloridize and render insoluble any sulphate of silver which may be present. From the clear lixivium thus obtained, after adding the requisite amount of chloride of sodium, the copper is precipitated, as already described, by the action of sulphurous-acid gas. The resulting acid liquid, freed from the excess of sulphurous acid by the addition of a reserved portion of the original solution containing copper chloride, and still retaining more or less copper, is now used to dissolve the oxide of copper from a portion of the lixiviated ore; the process being aided by heat, and, if the formation of dichloride of copper is to be feared, by the injection of a current of air, which may be made the means of heating and agitating the mixture. If the ore contains

* I have found calcined sulphuretted copper-ores to contain, in addition to soluble cupric sulphate, and insoluble oxides of copper, a small portion of a cuprous compound, which, though insoluble in water, is dissolved by a hot and strong solution of common salt, and is probably a cuprous sulphate or sulphite.

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silver, either in the form of metal or unoxidized sulphide, we have in the chloride of copper which is formed the best agent for bringing it to the condition of chloride of silver. This will be found in the residue after the extraction of the copper, together with any gold which may be present, lead as sulphate, oxides of antimony and iron, and earthy matters. Cobalt, nickel, and zinc, if present will, however, be dissolved, and not being precipitated by sulphurous acid, will, by successive operations, accumulate in the solution, and may afterwards be extracted.* From the residues thus deprived of copper we have found the silver to be readily dissolved by brine,† after which, if gold be present, it may be removed by chlorination, or the two precious metals may be extracted together from the residues by amalgamation. When, as in the case of certain mattes from Utah, for example, the residues contain a large amount of lead as sulphate, this may be recovered by smelting, and a base bullion got containing the precious metals. The same result may also be attained by smelting the residues with an admixture of a lead-ore.

Chloride of silver is soluble to some extent in solution of cupric chloride, and is then in part carried down with the cuprous chloride in the precipitation of the latter. The formation of cupric chloride may be avoided by adding to the solution of sulphate of copper little more than the amount of chloride of sodium necessary for the conversion of the copper into dichloride. In this case, as we have seen, the acid liquid after precipitation by sulphurous acid will contain chiefly sulphuric acid, though still holding sufficient cuprie chloride to effect the chloridizing of any silver which may be present in the ore.

The dichloride of copper, as obtained by precipitation, is a white coarsely crystalline powder, having a specific gravity of 3.376 (Playfair and Joule), and, as we have seen (note on page 14), is nearly insoluble in cold water. After being washed from the acid liquid, it may be readily reduced by placing metallic iron in the moist dichloride, which should be covered with water to exclude the air. The action spreads rapidly through the precipitate, so that a single mass of iron will, in a few hours, change a considerable volume of dichloride around it into pure spongy metallic copper. The reduction of copper from solutions obtained in those wet processes where

* For observations on the association of nickel and cobalt with certain copper-ores, see Appendix I.

† For notes on the solubility of chloride of silver in solutions of common salt and other chlorides, see Appendix II.

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the copper exists as protochloride, often accompanied by salts of iron, entails a considerable loss of metallic iron, and gives a copper which is impure from the presence of basic iron-salts. The reduction of the solid dichloride, however, presents none of these disadvantages. Forty-five parts of iron suffice to reduce one hundred parts of copper; the precise ratio being as 28.0 : 63.4. The ferrous chloride which remains in solution may with advantage be used instead of chloride of sodium for chloridizing subsequent solutions of sulphate of copper, ferrous sulphate being formed which, as it accumulates, may be separated by crystallization from the acid liquid. The ferrous dichloride required to chloridize twenty parts of copper would equal about sixty-one parts of hydrated ferrous sulphate.

Another mode of treating the dichloride, which may in some cases be resorted to, consists in decomposing it, best at a boiling heat, with a slight excess of milk of lime. The dichloride is by this means converted into a dense orange-red suboxide of copper which, after being washed from chloride of calcium, in a filter-press or otherwise, and dried, may be readily reduced to metallic copper in a reverberatory furnace. For this reaction, 28.0 parts of pure quicklime are required for 63.4 parts of copper, and the resulting chloride of calcium may be used instead of chloride of sodium or chloride of iron for chloridizing solutions of sulphate of copper. In this case, there will be formed an insoluble sulphate of lime or gypsum, while the free sulphuric acid of the solution is replaced by chlorhydric acid. The use of the chloride of calcium would, however, require an additional operation, since, to avoid the presence of the precipitated gypsum either with the dichloride or the undissolved residue of the copper-ore, it would be necessary to add the chloride of calcium to the clear copper-solution, and, after allowing time for the gypsum to subside, to transfer the liquid to the vats in which the copper is to be precipitated by sulphurous acid. There may, however, be localities in which the cost both of metallic iron and of common salt is such as to render advantageous the decomposition of the dichloride of copper by lime, provided there is no silver to be extracted.

We have heretofore considered only the case in which the acid liquor got by precipitating the copper from neutral solutions in the form of dichloride is used to dissolve successive portions of oxide of copper alone. This can be done in the case of pure ores free from other strongly basic oxides, if without loss, yet without any gain of acid save what comes incidentally from the portion of sulphuric anhydride which is given off in the calcination of pyrites, or from

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the reaction between sulphurous acid and oxygen in the presence of chloride of copper, as already explained. If, however, as is more often the case, we are treating artificially oxidized sulphuretted ores or mattes, which yield by roasting a mixture of oxide and sulphate of copper, it will be apparent that by the repeated use of the present process there must result a constantly augmenting proportion of free acid in the liquid.

This may be made clearer by examples. Let us suppose a solution holding in a cubic foot (equal 1000 ounces of water) 63.4 ounces or two equivalents of copper in the form of sulphate. To convert this into protochloride would require two equivalents or 117 ounces of chloride of sodium, but for the production of the dichloride, as we have seen, one equivalent, or a little more, will suffice, or, in place thereof, a corresponding amount of ferrous or calcic chloride. When, by the action of sulphurous acid, the whole of the copper is reduced to the cuprous condition, and in great part thrown down as dichloride, the previously neutral solution will contain two equivalents or 98 ounces of sulphuric acid* (oil of vitriol), which, if a larger amount of chloride had been added, would be in part replaced by chlorhydric acid. These two equivalents of acid are capable of taking up two equivalents, or 79.4 ounces of oxide of copper, after which the solution will contain, as at first, 63.4 ounces of copper. If, however, we add to this acid solution, instead of simple oxide of copper, a calcined ore or matte in which one-third of the copper is present as soluble sulphate and two-thirds as oxide, it is clear that when the acid is saturated we shall have in the liquid, besides the 63.4 ounces of copper from the oxide, one-half as much more, or 31.7 ounces of copper which were already present as sulphate in the roasted ore; making in all three equivalents or 95.1 ounces of dissolved copper, which are, in their turn, to be converted into dichloride. Now, as the amount of acid set free in this reaction is equal to that originally combined with the copper, it follows that the liquid after the precipitation of the dichloride will contain three equivalents of acid, instead of two as before. If to this we add, a second time, enough of the mixture of two-thirds oxide and one-third

* While we recognize the dyad nature of copper, oxygen and sulphur, and the bibasicity of sulphuric acid, it is simpler and more convenient for the calculations of the manufacturing chemist and the metallurgist to use, as we have done in the present paper, the older notation, and to speak of 31.7 parts of copper, 8 parts of oxygen, 40 parts of sulphuric oxide, 49 parts of oil of vitriol, 36.5 parts of chlorhydric acid, and 58.5 parts of chloride of sodium as equivalents.

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sulphate of copper to neutralize these three equivalents, we shall have four and a half equivalents of dissolved copper, from which, by a third repetition of the process of precipitation by sulphurous acid, four and a half equivalents of sulphuric acid would be set free; so that in place of 98 ounces we should have 220½ ounces in the solution;—an amount which a fourth repetition of the process of saturation and precipitation would raise to six and three-quarter equivalents or 330 ounces of oil of vitriol.

If, instead of a mixture containing one-third of its copper as sulphate, we have one in which only one-fourth is sulphate and three-fourths are oxide, we should get by saturating with this a solution containing two equivalents of acid, and subsequent precipitation with sulphurous acid, a liquid holding 2.66 equivalents of free acid, which by a third repetition of the process would yield 3.55, and by a fourth 4.73 equivalents of free acid, in place of the 2.00 equivalents which were present after the first precipitation.

The above calculations are founded on the supposition that the roasted ore or matte contains, besides the oxide of copper, no base that would be attacked by dilute acids. In fact, however, oxides of lead, zinc and, more rarely, nickel and cobalt, may accompany the copper-oxide, and give rise, the first to an insoluble and the others to soluble sulphates, consuming more or less acid. Ores containing more or less carbonate of lime (often with carbonate of magnesia) are also of frequent occurrence, and here is seen a great advantage which this mode of copper-extraction possesses over all the other wet processes; for since lime and magnesia, and their carbonates, not only neutralize free acids, but throw down copper from its solutions, the treatment, by these processes, of ores containing any considerable proportion of calcareous matter is impracticable. With the process here proposed, which generates an abundance of free acid, the extraction of copper from ores which do not contain an excessive amount of calcareous matter presents no difficulty except such as arises from the mechanical obstacle created by the formation of gypsum in the solutions. The accumulation of acid in the bath is indeed so rapid in many cases that it will become unnecessarily strong, and may be diluted with water; while that portion not needed, after being deprived of the last portions of copper by the action of metallic iron, may be rejected unless it retains in solution other metals of value.

It will be seen from the foregoing description that the new process here described resembles those which, at the beginning of this paper,

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we have placed in Class II, inasmuch as the oxidized copper is separated from foreign metals by dissolving it in sulphuric and chlorhydric acids; with the difference, however, that the acids for this purpose are generated in the process itself, by the action of sulphurous acid; while the copper is separated from its solutions in the form of dichloride, the reduction of which to pure copper is readily effected by the consumption of a minimum amount of metallic iron. At the same time, any silver or gold which may be present in the ore is left undissolved, and in the best condition for subsequent extraction by well-known methods; while the saving of cobalt and nickel, of lead, or of antimony, should these be present in quantities of economic importance, may be subsequently effected by very simple processes.

The apparatus for this new general method of copper-extraction is simple and inexpensive. The chlorine required in the precipitation of the copper being recovered for further use, the only reagent consumed, except the sulphurous acid—which is a waste product from the roasting of sulphurous ores—is an amount of iron which is equal to less than one-half the weight of the copper, and may be recovered in the form of sulphate of iron,—or, instead thereof, the same quantity of caustic lime.*

Appendix I.

The presence of small portions of cobalt and nickel in cupriferous pyrites is not uncommon, and mixed earthy oxides of copper, nickel, and cobalt have been found in considerable quantities in Missouri. A greenish, translucent, amorphous mineral, with black stains, resembling chrysocolla in appearance, from some place in Western Nevada, where it was said to be abundant, and to have been mined for the manufacture of sulphate of copper, was brought to me in 1876, and found to contain considerable quantities of both cobalt and nickel. One of two closely agreeing analyses by my former pupil, Mr. Hardman, made at the Mass. Institute of Technology, in 1877, gave for this mineral as follows: Oxide of copper, 9.63; oxide of nickel, 3.23; oxide of cobalt, 3.88; peroxide of iron, 3.08; peroxide of manganese, 2.40; lime, 1.04; magnesia, 0.10; alumina, 13.01; silica, 42.97; water, 18.38 = 97.72. The cobalt

* United States letters-patent, No. 227,902, for this method of copper-extraction were granted to Thomas Sterry Hunt and James Douglas, Jr., May 25th 1880.

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and nickel were separated by Rose's method. Another analysis, in which these metals were separated by the method of Fischer, with nitrite of potassium, gave of oxide of cobalt, 4.11. Such an ore, if abundant, would be a valuable source of both nickel and cobalt.

This aluminous mineral, like chrysocolla (*ante*, page 12) is attacked by a solution of ferrous chloride and common salt, by which the oxides of cobalt and nickel are indirectly dissolved; since, although they have not the power of decomposing ferrous chloride, they decompose the cupric chloride which is formed by its reaction with cupric oxide.

Appendix II.

As regards the solubility of chloride of silver in solutions of chloride of sodium, Vogel found that one liter of a saturated solution, at ordinary temperatures, held dissolved 0.950 grams of chloride of silver, while according to Hahn, a liter at 19.6° C. holds 1.269 grams. Becquerel found at ordinary temperatures for a similar solution 0.800 grams to the liter. 100 parts of water, saturated at 100° C., hold 26.61 parts, and at 15.6° C., 26.34 parts of chloride of sodium, the densities of the solutions being respectively 1206.93 and 1204.03. Hence, one liter of a saturated solution at 15.6° holds 316 grams of common salt, 1000 parts of which solution under these conditions dissolve, according to Hahn, at 15.6° C., 3.0 parts of chloride of silver; while, according to the observations of Vogel and of Becquerel, at "ordinary temperatures," not defined, 1000 parts, in saturated solution, dissolve respectively 4.0 parts and 2.53 parts of chloride of silver. The latter figure approximates to that given by Pelouze and Frémy, according to whom 1000 parts of salt at 18° C. hold dissolved 2.40 parts of chloride of silver. The solvent power, according to these chemists, varies greatly with the temperature, the amount dissolved being equal to 1.70 parts at 10° C., and not less than 6.80 at 100° C., while at 0° C. but traces of chloride of silver are dissolved. Differences of temperature may suffice to explain the discrepancies between the results of Vogel, Hahn, and Becquerel, but not those of Pelouze and Frémy at 18.0° C., a temperature above that mentioned by Hahn. It is possible that these chemists may not have employed solutions saturated with chloride of sodium, to which the observations of the others refer. Fresenius, speaking of the solubility of chloride of silver in hot concentrated solutions of the chlorides of sodium, potassium, ammonium, calcium, zinc, etc., says "On sufficient dilution with cold

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water the dissolved portion separates so completely that the filtrate is not colored by sulphuretted hydrogen."*

As to the solubility of chloride of silver in some other chlorides, Hahn found that a liter holding 30.70 per cent. of ferrous chloride, and having a specific gravity of 1.419, dissolves, at 20° C., 2.385 grams of chloride of silver; while a solution, holding 44.48 per cent. of cupric chloride, and having a specific gravity of 1.5726, dissolves at 30° C., for 1 liter, 0.836 grams of chloride of silver. For farther observations on the solubility of chloride of silver in other chlorides, see Percy, *Metallurgy of Silver and Gold*, Part I, p. 58, and also Hahn, *Transactions of the American Institute of Mining Engineers*, Vol. II, p. 99.

INVESTIGATIONS ON THE ORE KNOB COPPER PROCESS.

BY T. EGLESTON, PH.D., NEW YORK CITY.

THE works of the Ore Knob Copper Company are situated in the county of Ashe in the northwestern part of the State of North Carolina, about ten miles from the Virginia line, at an elevation of 4600 feet above the sea. The nearest railroad station is at Marion, Smythe County, Virginia, about forty-five miles distant. The roads from the railroad to the works have been constructed by the company for the transportation of their material, and are very hilly, and in certain seasons of the year in bad repair. Transportation is therefore always limited and never easy, although it is done by contract at a very low price. The main difficulty with the transportation is not so much its cost as the fact that it puts a limit to the production of the works. These unfavorable conditions make it necessary for the owners of the mine to smelt their ores and to send to market nothing except the metal, which alone will bear the cost of transportation.

The mine was opened previous to 1860, but has only been worked systematically during the last five or six years. The vein is a fissure vein from ten to twenty feet in thickness in the gneiss of the

* Fresenius, Quantitative Analysis, Amer. Ed., 1879, p. 124.

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Laurentian period, and has been explored over a long distance by working and trial shafts. It has a strike of north about sixty degrees east, and is vertical, cutting across the strata of the country rock. One wall is always sharply defined, the other is in the rock; the ore dies out in it. Its penetration is very nearly constant, but there is no seam to give a sharp separation. The gossan generally outcrops at the surface. When it does not it is covered by only a few feet of earth, so that there is no difficulty in following it, which has been done for nearly a mile. It is generally from forty to fifty feet thick over the ore, and the only dead work which has to be done is the piercing of this gossan to reach the ore. All the shafts and levels are in the ore itself, so that in the mine no dead work has to be done. Both the walls of the vein are vertical, and as they are very strong, the ore between them is all taken out, it being only necessary to leave sufficient of it between the walls to protect the shafts. Two of the shafts are sunk to a depth of three hundred feet, and two to two hundred and fifty each. Five other shafts to the north have been sunk at variable distances, the shallowest of which is sixty feet, and two others to the south are now being sunk on the gossan. Only two of the shafts are being used to raise ore at the present time. The others are either in poorer ore than these two shafts, or are not worked, because it is thought advisable to follow the ore to the south, where it seems to be running richer than toward the north. The ore consists of pyrrhotite mixed with chalcopyrite and quartz in variable proportions. Hardly any other minerals except a small amount of carbonate of lime, some little black mica, and occasionally garnet, can be seen in the rock.

The method of mining employed is known as underhand stoping, this method being the best suited for the character of the vein. The rock is hard, but the ore is won without much difficulty. Negro labor is employed to a very large extent, and, so far as my experience goes, I have found it as good, if not better than white labor, and much more tractable. The wages paid are low, but the work performed is equal to that done elsewhere, for while the actual money paid is small in amount, its purchasing power is as great, or even greater, than a much larger amount paid elsewhere. The store system, which is adopted, allows the miners to get good and substantial articles at a much lower price than they can purchase them elsewhere, thus rendering them contented, and yielding besides a large revenue to the company.

The method of extraction is by iron buckets. These hold from

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1600 to 2000 pounds each. They are placed on a truck which, when loaded is rolled to the shaft, and the buckets are there hoisted. The ventilation of the mine is excellent, the foul air of a blast being removed in a very short time.

The mine was originally opened on a very rich streak of chalcosite running at times as high as 30 per cent. in copper. The works which were constructed to treat it were designed for the Hunt and Douglass process, which has been elsewhere described in full.* This process was worked on a large scale until the amount of carbonate of lime which came into the ores rendered it impossible to use it any longer. It was then abandoned and the present works built. The ore afterwards became poor, and no traces of chalcosite are now seen in the mine.

The smelting works are situated only a few hundred feet from the mine. The ore is delivered into the dressing-house, where that containing copper is separated from the sterile material, and discharged into a car running by gravity to the smelting works, where it is dumped into carts and carried to the piles to be roasted.

After a series of experiments, extending over many months, it has been found that at present prices an ore containing 3 per cent. of copper just pays the expenses of mining and smelting. There will, consequently, be a loss at Ore Knob, under the present conditions, in working by the method now used an ore of a less, and a profit in working those of a higher percentage.

As the mine and the works are so near together no special provision for storing the ore is made except in the roasting piles. The ore goes from the mine to the dressing works, and from there it is delivered in cars to the shoots, which dump directly into the carts which carry it to the roasting-piles. There are about two thousand tons of poor ore, however, lying upon the surface, broken and ready to smelt whenever a process can be found to work it profitably, or when the price of copper shall be high enough to make it worth while to mix this ore in small quantities with the ore as it comes from the mine.

Analyses No. 1 and No. 2 show the mineralogical composition of the ore taken from each of the two shafts of the mine. No. 3 is a sample taken from the heaps of poor ore lying on the surface.

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* See Engineering, London, Eng., vol. xxii., p. 419. Trans. Am. Inst. Mining Engineers, vol. i, p. 258, vol. iii, p. 391.

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	No. 1.	No. 2.	No. 3.
Chalcopyrite,	11.33	13.30	4.76
Pyrrhotite,	37.46	35 74	48 78
Sesquioxide of iron,	8.14	16.34	18.36
Alumina,	1.84	1.49	
Manganese,	0.16	0 50	0.76
Lime,	5.32	7.84	7.21
Magnesia,	0 35	0.94	0.30
Carbonic acid,	4.76	7.19	6.00
Zinc,	0.67	0 66	0.65
Cobalt,	0.09	0.09	0 095
Nickel,	0.71	0.92	1.08
Silicious residue,	29 10	13.57	12 80
	99.93	98.58	100.79
Metallic copper in the ore,	3.92	4.60	1.65

Alkalies, etc., not determined.

These analyses show the ores to be of exceptional purity. No trace of arsenic or antimony could be found in any of the samples.

About fifty per cent. of the ore mined is sent to the smelting works. The amount of ore mined in June, 1880, was 2171.7 tons; that sent to furnaces was 1413.5 tons, which is 65 per cent. of that mined. The amount of ore mined from July 1st to 8th, 1880 (6 days), was 564 tons; that sent to the furnaces was 320 tons, or 56 per cent.

The ore might be enriched much further by careful hand-picking. No dressing in the ordinary sense of the word is applicable to it, since the pyrrhotite and chalcopyrite are of very nearly the same specific gravity. No effort is made at dressing, except with the "fines," and the only attempt then made is to get rid, in a rough way, of part of the quartz in the ore.

The following interesting summary of the cost of mining and the production from January 1st, 1879, to April 1st, 1880, was taken for me from the books of the company by Mr. J. E. Clayton.

COST OF MINING.

Cost of labor, for fifteen months,*	$27,706 11
Cost of powder, fuel, candles, etc.,	8,499 24
Cost of carting, per ton of ore,	0 815
Quantity of ore delivered in mill-house,	38,372 tons.
Ore delivered yielded in furnace ore,	21,223 tons.
Proportion of furnace ore to ore delivered,	55.1 per cent.
Average yield of the ore,	6 per cent.

* The labor of sinking over three hundred feet of shafting and all the development in the mine is included in this amount.

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Yield of furnace ore from ore mined, 1876,	33 per cent.
Yield of furnace ore from ore mined, 1877,	34 per cent.
Yield of furnace ore from ore mined, 1878,	48 per cent.
Yield of furnace ore from ore mined, 1879 and 1880, to April 1st,	55.1 per cent.

COST OF LABOR IN DETAIL.

Cost of assorting, handling, and selecting,	$12,447 66
Cost per ton of assorting, handling, and selecting,	0 8233
Cost per ton of handling, assorting, and delivering at furnace,	0 586
Cost of surface work for fifteen months,	8,802 63
Cost per ton of furnace ore, surface work,	0 415
Cost of superintendent, managers, and bookkeepers,	7,500 00
Cost of superintendents, managers, and bookkeepers, per ton of ore,	0 208

WAGES (INCLUDING BOSSES)—UNDERGROUND.

Seventy-two men, average daily pay,	$0 92½

WAGES—SURFACE.

Assorting ore, thirty-nine men, average daily pay,	$0 79½
Furnace men, eighty-seven, average daily pay,	1 06½
Averag daily pay for past fifteen months,	0 89½
Average number of men directly employed at the mine,	220

The arrangement of the metallurgical works appears at first sight not to be very regular, but their position has been determined by the lay of the ground. They consist of six roasting sheds, ten shaft furnaces, one reverberatory furnace, and four houses for storing the coal.

The fuel used is wood for roasting and refining, and charcoal for the shaft furnaces. The lower furnace house, Plate 1, is 124 by 54 feet; it contains four ore furnaces, with four dust chambers, and outside of it at the lower end is an engine and boiler house, 33 by 35 feet. Directly behind it is a charcoal shed 212 feet long, and towards the upper end two ore-roasting sheds, one 300 and one 280 feet long. The three matte-roasting sheds lie between the two furnace houses. One of these is nearly in line with the lower furnace house, 100 feet from it. Behind this house, 50 feet distant, and at right angles to it are two other matte sheds, one 75 feet and the other 120 feet long. The upper furnace house, Plate 1, is 180 by 56 feet, with an engine and boiler house at the lower end 33 by 35 feet. It contains four ore, two matte, and one refining furnace. Behind it and on a level with the throat of the ore furnaces are one ore-roasting and two charcoal sheds, each 120 feet long. The upper and lower furnace houses are about 400 feet apart. They are situated on the crests of

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hills, the sides of these hills being utilized as dump piles for the slags, which have already accumulated to a considerable height, but there is still space for them for many years to come.

The plant is capable of producing a much larger amount of copper than it now does. The ore, as seen by the analyses, is so exceedingly pure, and the fuel so entirely free from everything deleterious, that with careful refining a very high grade of copper might be made.

The works are very favorably situated with regard to fuel. The company owns a large amount of timber land, which, however, it has been thought good policy to leave untouched. They contract for their wood with the neighboring farmers, who deliver it ranked at the following prices:

All oak, per cord,	$1 85
Mixed oak, "	1 65
Soft wood, "	1 50

This wood when delivered is ranked up beside the roasting sheds on the side from which the prevailing wind comes and is the only protection the sheds have against the weather. The charcoal is purchased by contract at five cents per bushel of from 18 to 19 pounds, delivered at the furnace. The wagons are numbered and their capacity gauged. The receiver gives a ticket which is good at the store for a specified amount of supplies and a certain percentage of money. The charcoal is delivered by drawing out the bottom boards of the cart; it falls in a pile underneath, and after careful inspection is stored in the houses, of which there are four, containing 13, 35, 66, and 70 thousand bushels each. The farmers cut their wood in the summer and burn it at once, and are not generally skilled in the manufacture of charcoal, many of them having only just learned it; therefore, only a very small percentage of the combustible part of the wood is utilized. The wood is often cut and immediately put into the piles with the leaves on. The practice of cutting wood in the summer for industrial purposes is general in the South, and is a very bad one, for not only is the wood so cut of poor quality, but the charcoal made from it is very light, as all the pores of the wood are open at that time. The farmers do not seem to care to get the full value of their material, but regard any money in hand as a profit, and count the material used, and their own labor for everything else, except for their crops, as clear gain.

As the charcoal is delivered by contract, and all they are paid for

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it is considered by the farmers as profit, with no regard for the intrinsic value of the material, it would seem as if neither they nor the works had any interest in having it made one way or another. But this is not so; good metallurgical charcoal can only be made from wood cut in the proper season, and burned in the proper way. If the fuel is not all that it should be two things will result; first, more of it must be used to get the proper temperature; second, the furnace will be constantly liable to accidents, which increase the cost for fuel, decrease the output, and increase the labor necessary at any given time. I had occasion several times to notice accidents and delays attributable solely to the inferiority of the fuel. It would be wise to construct a few kilns* for the farmers on terms which could be agreed upon. I think this would show that the method of kiln burning is very advantageous to both parties, as the kilns cost but little and need very few repairs.

All other materials are very cheap, as there is no market in the vicinity but at the mine. It regulates the prices of most of the articles produced in the country. Bricks cost $5 per thousand; lumber, $10 per thousand feet; labor is cheap and there is always an abundant supply of it, but from the prices of country produce given below, it will be seen that the purchasing power of money is much greater than it is in most places:

Butter,	8 to 12 cents per pound.
Beef,	4 to 4½ " "
Mutton,	3½ to 4½ " "
Chickens, grown size,	10 cents each.
Turkeys,	35 to 50 "
Eggs,	6 to 10 cents per dozen.
Corn,	50 to 60 cents per bushel.
Wheat,	80 to 100 " "
Hay,	$8.00 to 12.00 per ton.

Pig copper is arrived at in four and ingot in five operations. The process consists of:

1. Roasting the picked ore and the dressed fines in piles.
2. Fusion in a shaft furnace for mattes, generally called single mattes.
3. Roasting the mattes (Nos. 2 and 4) in piles.

* See Transactions Am. Inst. Mining Engineers, vol. viii, p. 378.

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4. Fusion in a shaft furnace for black or pig copper, and concentrated or double mattes.

5. Treatment of the salamanders.

6. Fining and refining.

1. ROASTING THE ORE.

The roasting of the ore is effected in three sheds, each 34 feet wide, and 300 feet, 280 feet, and 240 feet long respectively. They are 8 to 10 feet to the first timber, and 20 feet to the peak of the roof. These three sheds are capable of holding 42 piles, 16 in the first, 14 in the second, and 12 in the third. These piles are 17 by 20 feet, and 8 feet high in the middle, and contain 100 tons of fresh ore and about 50 tons of partially roasted ore, so that in all, each pile holds about 150 tons. The bottom of these ore piles is made directly on the ground. Very fine ore is put down first to a depth of from ten to twelve inches. In taking up this fine ore after roasting the ore floor is hollowed out, so that it gradually becomes deeper. Over the fine ore three cords of good wood are placed in two rows beneath the whole piles; three rows are made upon the outside so as to form a barrier to hold up the sides of the pile. The ore, which is broken to about the size of the fist, is piled over the wood. It is dumped from carts under the sheds, to form the ends of the pile, and is shovelled to the sides and the centre. On the sides and ends it is left to take its natural talus. The outside of the pile is covered with ore in pieces about the size of a hickory-nut, and the fine unfinished ore is placed on the top and sides of the piles, then the very fine screenings over this on the top and sides. On the bottom at the sides the piles almost touch. Three piles of fresh ore were being roasted, two were being taken down, three were being built, and two roasting spaces were empty at the time of my visit. The carts come in quickly as they are wanted. They are loaded from a bin at the end of the inclined tramway coming from the dressing-house, by drawing a slide.

As the ore contains a very large amount of sulphur, owing to the presence of so large a quantity of pyrrhotite, but little fuel is required for the process. The greatest part of the heat is due to the sulphur in the ore. The pile soon settles from the burning out of the wood, when the men make the cracks tight with fine ore, leaving only just enough of them open at the bottom of the pile to insure the propagation of the heat from below up, and to draw it to any point where there may have become too cool, which is easily accom-

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plished, owing to the way in which the pile is built. It requires but little labor to take charge of such a pile since, if it is properly constructed and kept free from the influence of high winds, the heat of the burning sulphur spreads itself upward in layers sufficiently horizontal to insure a nearly equal distribution of the heat. The ease, however, with which the air has access to the pile, will cause some irregularities, as will also the size and nature of the pieces of the ore, so that it is never uniformly roasted. In driving off the sulphur, sufficient must be left to form the matte, but enough must be driven off to insure that, as much of the iron as possible shall pass at once into the slag. The pile is lighted at the four corners. It takes about twenty-four hours to get it well burning. Fine ore and small pieces are put round the bottom against the wood, after it is well started, to prevent its burning too fast, the thickness of the cover being varied in order to regulate the rate of burning. It takes about six weeks to burn a pile. When taken down it is about three-fifths roasted, and the rest goes into a new pile. The fine ore on the bottom is generally entirely agglomerated, so that it has to be broken with a pick or sledges. Any ore that is not well roasted goes into the new pile. The piles are discharged before they become cold.

Three men and two horses and carts are required to bring the ore to the piles. Four men are required to clean them up, and dress and break the masses, which have become agglomerated in the process of roasting. Two piles a week were taken down during my visit. There are usually about seven broken piles in process of removal at one time. The men at the piles work on ten-hour shifts.

The analyses of the roasted ore is given below.

	No. 1.	No. 2.
Copper,	4.68	8.94
Iron,	39.08	38 38
Sulphur,	6.76	7.64
Alumina,	1.79	2.68
Manganese,	0.40	0.86
Lime,	8.10	8.01
Magnesia,	0 88	0.65
Silicious residue,	15 20	17.52

In order to be sure of an average result the assay sample for No. 1 was taken from the carts going to the ore furnace, a shovelful being taken from different parts of each cart. For No. 2 the ore was taken from the different piles, the sample being taken from the bottom to the top.

As the ore and the mattes made from them are roasted in the open air, the sulphurous smoke given off from these piles is injurious to vege-

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tation, so that the region over which it reaches is completely denuded. No very great inconvenience results from this at the present time, as the company owns all the territory affected. Much of the sulphur thus lost might be made a source of revenue to the company by utilizing it in some process of working the poor ores, now an obstacle to the opening of the mine, and an incumbrance on the surface. The cost of wood, it is true, is very small, but if this ore were roasted in furnaces, less wood would be used, and the roasting would be more thoroughly done. All the conditions under which roasting in piles is profitable exist at the Knob, but the very best wood is now used in the process instead of refuse and poor material. A furnace plant to do the same work would require an outlay, but in the end would be cheaper in fuel, and require a much smaller stock of ore in the piles, which is really equivalent to an increase in the product of the mine. If the poor ores are ever to be worked it must be by some method which involves the saving of the sulphur.

The roasting of the ore is imperfectly done, but the ore is of such exceptional purity that there are but few disadvantages resulting from the hasty roasting, the most serious one being that the matte is not as rich as it might be, and more foreign matter than necessary must be put through the next operation.

DETAILED STATEMENT OF COST OF ROASTING AT ORE KNOB; TAKEN FOR FIFTEEN MONTHS, FROM JANUARY 1ST, 1879, TO APRIL 1ST, 1880.

Hauling to ore sheds, { 8 men at 75 cents, $2 25, / 2 carts and horses at 40 cents, $0.80, } .	$3 05
Placing ore and caring for ore heaps, 1 man $1.00, 3 men 75 cents,	3 25
	6 80
(Average amount of ore roasted per day 50 tons of 2000 pounds.)	
Average amount of fuel used per day 1½ cords of wood at $1 85, .	2 77
Cost for 50 tons, ...	$9 07
Cost per ton, ...	0 1814

The ore is delivered in cars on the tramway near the furnaces.

Of the piles of ore, at the time of my visit, 3 were being made, 20 were roasting, 5 were being cooled, 10 were cold, and 4 places were empty.

2. FUSION FOR MATTES.

The roasted ore, as soon as taken from the piles, is carried to the shaft furnaces, Plate II. The furnaces used for smelting ore and matte are almost identical in construction. There are eight ore furnaces, which, when they are all running, produce forty tons of matte, or about five tons each in twenty-four hours. Four of them

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were not in blast. The furnaces are rectangular in section, and have two tuyeres in the back of the furnace 3 inches in diameter, with nozzles 2¼ inches in diameter. The tuyeres converge so that lines passing through their centres meet at 21 inches from the nozzle. The material of which the furnace is built, as shown in Plate II, is partly soapstone and partly firebrick. The whole of the furnace below the tuyeres is made of crushed quartz.

The furnace is 2 feet 4 inches wide at the tuyeres, and 3 feet 10 inches under the tymp. It is 8 feet 10 inches high on the tuyere side, and 9 feet 4 inches on the breast side. The plan gives a section on the line of the tuyeres and at CC above, showing that the interior tapers slightly on all sides except at the breast. The tymp is made of a piece of soapstone 6 by 12 inches, which goes across the whole front of the furnace. Above this stone the walls are 8 inches thick, built half of firebrick on the inside, and the other half of common brick* on the outside to a height of 40 inches, where an iron bar 1½ by 4 inches supports the soapstone above on the tuyere side. There is a soapstone 12 × 18 × 54 inches above the tuyere. The firebrick is here carried up 4 feet. The red brick is carried part of the way to the same height, and the rest only 3 feet, the soapstone here being supported by an iron bar of the same size as on the breast side. By this arrangement the whole of this part of the furnace can be taken out without disturbing the rest. The tuyere is 12 inches above the hearth, which inclines to the front so as to be there 18 inches below the centre line of the tuyere. The dam-stone S, does not exist in the ore furnace, but goes across the front of the pig-copper furnace, which is in all other respects exactly similar; it has a rounded cut on the inside and also on the under side.

On the front of the furnace is a fore-hearth made of pieces of cast iron bolted together. It is 5 feet wide and 30 inches high next the furnace, and 28 inches wide and 2 feet high on the front. In the middle of the front a spout is bolted on for the slag to flow over. This box is filled and carefully packed with a mixture of equal parts of steep and river sand. The steep is made of one part of burned clay and two of charcoal dust. The hearth is then finished in crushed quartz, when the tap hole is cut out through a hole made on one side through the cast-iron plates, and is closed with quartz sand, wetted so as to pack. It is easily opened with a pointed iron bar at first, but in about ten days it gets hard, and has to be

* The bricks made at the works are now used exclusively in the place of common red brick.

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cut out with a steel-pointed tool. The soapstone which is used in the construction of the furnace comes from the neighborhood, and is contracted for at fixed prices.

The bricks used are made at the works, of two-thirds of crushed quartz and one-third clay. The mixture is sun-dried and built into the furnace, and dried and burned in place. No bricks are burned outside of the furnace.

Next to each furnace, and connecting with it directly, is a large dust chamber, which is 4 × 8 × 16 feet on the inside. Access to it is had by a door on the casting floor, which is closed and luted tight when the furnace is at work. Between the furnace and the dust chamber there is an arched opening three feet wide, to admit of free circulation.

The cost of construction is given in detail below:

COST OF COPPER FURNACE AT ORE KNOB, NORTH CAROLINA.

144 cubic feet best soapstone, at $1.08,	$155 52
117 " common soapstone, at 96 cents,	112 32
1 M. firebrick,	10 00
8 M. common brick, at $6,	18 00
210 feet railroad rails, 50 pounds per foot, about 1½ tons, delivered here,	60 00
50 feet of 1¼ round iron and bolt ends,	9 82
20 square feet cast plates, 1 in. thick, 700 pounds, at 8 cents,	21 00
Mason's wages,	65 00
Helper's wages,	10 00
Mortar,	5 00
Blacksmith's work,	10 00
	$476 16

Dust Chamber.

18 M. common brick, at $6,	$108 00
1½ tons railroad rails,	60 00
961 pounds round 1¼-inch iron, at 4 cents,	38 44
Mason's wages,	27 00
Helper's wages,	10 00
Mortar,	12 00
Blacksmith's work,	8 00

Chimney.

16 M. brick for stack, at $6,	$96 00
Mason's wages,	30 00
Helper's wages,	15 00
1000 pounds iron, round and square,	40 00
Blacksmith's work,	6 00
Mortar,	11 00
	$461 44

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One-half cost of dust chamber and chimney for one furnace,*	$230 72
Cost of furnace,	476 16
Total cost of one furnace,	$706 88

The charging bed is made on the level of the throat with six loads of roasted ore, containing about 1500 pounds each, which is spread out over the charging floor directly behind the throat of the furnace. The charging floor is 22 feet wide and 120 feet long. It is continuous for the furnaces in both the lower and upper houses. Over the ore one load of about 800 pounds of cleanings from the front of the furnace is then spread. One load of the tips of the slag pots, containing foul slag, weighing about 1500 pounds, and one load, or 1200 pounds, of flue dust, mixed with clay, are then put on. This mixture of flue dust and clay consists of two-thirds of the former and one-third of the latter. The charging bed so composed is mixed with a shovel, and ten shovels of the mixture are charged to one basket holding about two bushels of charcoal, the size of the charge depending upon the heat of the furnace.

The slag runs continuously over the spout on the fore-hearth into a slag-pot placed in front of the furnace. To keep it from chilling charcoal in small pieces is placed on the runner. About four bushels per shift of twelve hours are used for this purpose.

The fore-hearth is always cleaned out just before tapping. Generally it is cleaned twice in the course of the twelve hours. Immediately after the last cleaning it is tapped. The tapping is made twice in twenty-four hours; 90 slag-pots per shift of twelve hours are filled. About half the slag used in the furnace is rich slag, which is added for a flux. The matte runs into a casting-pit lined with a steep made of one part of burned clay and two of fine charcoal. It is about two feet deep and four feet in diameter. The matte is taken off in disks as it cools, by means of hooks. This is the best method of casting, as it brings it into thin sheets so that it can be easily broken. Each casting-pit makes from nine to thirteen disks weighing about 1500 pounds apiece.

A campaign in the ore and matte furnaces lasts from 40 to 60 days. The men work on shifts of twelve hours in all the furnaces, the shifts changing at 1 A.M. and 1 P.M. If all the six ore furnaces were running on good ore, the output of the works would be not far from 500 tons of matte per month. The mine did not, how-

* The dust chamber and chimney are for two furnaces.

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ever, produce enough to keep more than two matte furnaces running in July, 1880.

The analysis of this matte is given below:

Copper,	23.41
Iron,	47.00
Sulphur,	22.08
Alumina,	0.40
Manganese,	0.24
Lime,	0 85
Magnesia,	0 88
Silicious residue,	0.57

The slags flowing from the furnace are separated into poor and rich. The rich slags are put directly back into the furnace; the poor are sent to the dump heap. The analysis of the rich slag from both the ore and the matte is as follows:

Copper,	1.85
Iron,	40.83
Sulphur,	2.87
Alumina,	4.84
Manganese,	1.17
Lime,	9.87
Magnesia,	1.12
Silicious residue,	25.96

These slags are a little more basic than a bibasic silicate. They are not, however, very infusible, owing to the large quantity of iron they contain. They flow freely from the furnace, but are a little pasty.

The analysis of the poor slag is given below. It was made of a sample taken from the slag heaps of both furnace plants. The sample was taken from all parts of the piles. It was collected in two carts, the whole of it crushed, and the sample for analysis taken from the crushed material:

Copper,	0.57
Iron,	40 88
Sulphur,	1.82
Alumina,	4.29
Manganese,	1.11
Lime,	9.59
Magnesia,	1.11
Silicious residue,	27.56

The poor slags do not differ essentially in composition from the rich, except in the quantity of copper they contain. They are generally produced a little before and at the time of casting. It would

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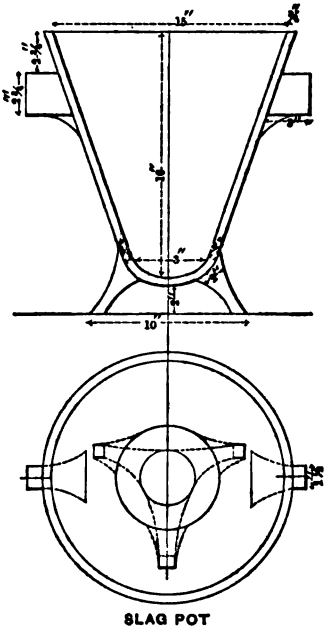
be better if these slags were more acid; they would separate more easily and attack the sides of the furnace less, but the iron would not be so rapidly separated nor the matte so rich. It is the very large quantity of iron present which makes all the difficulty in working the furnace and causes the short campaigns.

These slags run higher in copper than those made on Lake Superior, but I think will hardly be made poorer with the present fuel. If made with less copper the composition of the charge would have to be changed, or they would probably have to be submitted to a special treatment as at Pittsburgh, or be melted separately in a cupola as on Lake Superior, which would not pay. It would be much better to run the slags a little higher in silica, when more of the copper would probably pass into the matte. The slags in both these works are said to run as low as 0.25 per cent. in copper.

The number of slag-pots required for each ore furnace is seven. These pots, as shown in the figure below, are made of cast iron with



SLAG POT

lugs on the sides, so that they can be easily taken up and tipped. They stand on three legs, one of which is at right angles to the plane of the other two, so that it stands firm, and so that whatever way it stands it can be easily taken up by the slag buggy. The total number of slag-pots filled in the course of twelve hours is ninety. From the ore furnace four of these pots will contain rich slag.

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Only two of the ore furnaces were working in the lower furnace-house at the time of my visit. They were working well, but I think there would be an improvement if the ore were more carefully sorted. The casting is made about once in eight hours. Twice in the interval the furnace is worked to get rid of the accumulations of iron which form in the lower part of the furnace. The first indication of a foul hearth is a foul slag. Whenever the matte runs over with the slag the furnace is sounded and the charcoal over the apron is taken off to remove the obstructions.

The sticking in the furnace is caused by insufficiently roasted ore, and too high a temperature, which causes an energetic reduction of the iron, of which there is a very large quantity in the ore. When the obstructions are to be removed, the charcoal on the fore-hearth is drawn away, and the hearth worked with a heavy bar and sledges, and the accumulated material (charcoal, iron, and matte mixed) is drawn with a rabble over the side of the furnace, and cooled with water. This is repeated as often as necessary until the matte is cast. These half-melted masses of iron are put back into the furnace, if small, but if large are put to one side to be treated by themselves. After the furnace has been cleaned the slag does not run again for an hour or more.

When the furnace commences to engorge the charge is let down (at 4 A.M.). At 8 A.M. the furnace can be chiselled, which will take from three to four hours. The fore-hearth is then packed and the furnace filled with charcoal and allowed to stand from three to four hours and then charged. The furnace will be about twenty-four hours out. The furnaces were formerly chiselled once a week; it is now done about once in twenty days. The material so accumulated is always put to one side, to be submitted to the special treatment No. 5.

The blast for the six furnaces, four ore and two matte, in the upper furnace-house, is a No. 5 Root's blower, with a conduit-pipe 18 inches in diameter. The engine uses one and seven-eighths cords of wood per day. For the four ore furnaces in the lower furnace-house a No. 4 Root's blower is used, and the engine uses one and a half cords of wood per day.

Each furnace has one charger above and one below per shift of twelve hours, one slag-man, and one keeper. Besides these there is one slag-dumper for all the furnaces. The slag boy, in addition, picks the slag and brings it back to the furnace. The carts bring all the slag necessary for a charge.

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SMELTING THE ORE FOR SINGLE MATTES—TOTAL COST CHARGED AGAINST AMOUNT OF ORE SMELTED—LABOR AT FURNACE.

Two furnace-keepers, at $1.00,	$2 00
Two furnace-chargers, at 80 cents,	1 60
Two slag-rollers, at 80 cents,	1 60
Hauling ore, slag, clay, etc., to and from furnace, two men at 75 cents, one man at 60 cents,	2 10
Cost for keep of one horse and repairing cart,	40
	$7 70
Average ore smelted in furnace per day, 13 tons.	
Cost per ton for labor,	$ 60
Cost per ton for charcoal, 54½ bushels at 5 cents,	2 72
Cost per ton for labor and fuel,	$3 32

Ore,	13,686	tons.
Mattes,	4,326	tons.
Total,	18,006	tons.
Amount of charcoal used,	979,938	bushels.
Number bushels of charcoal used per ton,	54½	
Cost of charcoal per bushel, delivered at furnace,	5	cents.

3. ROASTING THE SINGLE MATTES.

The matte is broken up and is roasted in piles. This roasting is carefully done, but the same is true of it that was said of the ore roasting. The mattes require more fuel than the ore, and as they do not contain any arsenic or antimony, they could be roasted much better in a furnace, where they would be under complete control, than in piles, where they are exposed to the weather at all times. For this roasting there are three sheds, 240, 120, and 75 feet long, respectively, and 24 feet wide. The floors of all these matte sheds are paved with brick or stone. The piles are 14 by 14 feet, or about half the width of the shed, so that they can be turned from one side of the shed to the other. They are about five feet high, and as close together as they can be piled. There are fourteen piles in the long shed, and thirteen piles in the other two together. The pile is made by covering the floor of the shed with about two inches of fine charcoal, over which about one and one-fourth cords of good wood is placed, then one layer of large pieces and one layer of fine pieces.

The quantity of wood to be used requires judgment, as the mattes, especially the rich ones, are very fusible, and are likely to become agglomerated, in which case they would have to be picked out, broken, and passed through another roasting, which is never so completely done on these agglomerated masses as on the original

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mattes, which are cast thin for the especial purpose of having the action of the roasting such that the sulphur may be driven off, even to the interior of each piece, which can only be done when it is thin and flat.

The matte is brought in carts to the pile and dumped on it, and is then broken on the pile with hammers to about the size of the fist. In breaking the matte on the piles small pieces of black copper are sometimes found in it. These are carefully picked out. This black copper is formed mostly with the thin mattes from the next fusion. As the ore is so very pure, and contains no arsenic and antimony, the formation of black copper with the mattes is of little consequence. If it was formed in the ore fusion it would contain a very large amount of iron and would make very rich slags. Fortunately there is but very little of it. It is not kept separate from the other black copper, but is taken to the refining furnace.

As the concentrated mattes are very fusible, they should be broken to very small pieces and scattered about over the pile, so as to be in small proportion in any one place, and in this way to avoid any danger of agglomeration. There is but a small quantity of these thin mattes, so that the danger from fusion is not very great. When the pile is taken down all the fused or agglomerated pieces are picked out and put to one side, to be broken and put into the next pile, with the matte not sufficiently roasted. The parts which are finished are red and honeycombed. They are larger than they originally were, but have about the same weight, owing to the absorption of oxygen. The pieces that are not sufficiently roasted are collected, and are put on the outside of the piles.

It takes about five days to burn a pile, and the matte is roasted six times before it is ready for the furnace, taking about a month. From the first to the third roastings it takes ten days to finish each pile; the fourth and fifth, fifteen days each. As the piles occupy about half the width of the sheds they are turned from one side of the shed to the other, any agglomerated or large pieces being broken as they are transferred. Each pile contains about thirty-two tons. The number of piles required for the matte furnace is seventeen. One of these is being taken down fully roasted; one is being built with raw matte; two are being turned and fired every day by two sets of men. There are thus thirteen piles burning every day, and four not burning. Very often the material is taken to the furnace hot. One and a quarter cords of wood and eight bushels of charcoal are used for roasting one ton of ore.

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Two boys and one man are required to bring the matte. Besides this there are two men and one boy for each pile, to look after and turn it, or four men and two boys to do the whole work of roasting. One horse and two boys are employed in hauling the matte.

The analysis of the roasted matte is given below:

Copper,	18.26
Iron,	39.82
Sulphur,	3.38
Manganese,	0.28
Lime,	1.10
Magnesia,	trace.
Silicious residue,	14.50

COST OF ROASTING THE SINGLE AND DOUBLE MATTES.

Labor each turning, 8 men at $0.75 each,	$2 25
Wood " " 1¼ cord at $1 85,	2 21
Charcoal " " 8 bushels at $0.05,	40
Cost of one fire,	$4 86
Cost of six fires,	$29 16
Hauling to sheds, 2 men at $0.75, 1 horse and cart at $0.40, $1.90.	
One and a half day to each pile at $1.90 per day,	2 85
Cost per pile of 64,000 pounds,	$32 01
" " ton,	$1 00

4. FUSION FOR BLACK COPPER.

The roasted mattes are now fused for black copper and concentrated or double mattes. Two furnaces were constructed for this purpose, but only one of them was in use. They are exactly similar to the ore furnace, except the presence of the dam-stone, which is hollowed out on the back side and underneath. The furnaces are of necessity low, on account of the very large quantity of iron, which would be reduced if they were high. The pressure of the blast is three-fourths of a pound of mercury or twenty-one inches of water. The tuyeres are three inches in diameter, and are made of bronze They have been in use for two years.

In addition to the roasted mattes all the slags from the refining furnace—some of which, as will be seen by their analyses, contain considerable nickel and cobalt—are added to the charge in the furnace. The charging bed is made of three loads of matte weighing 1700 pounds, one load of rich slag, and fifteen shovels of clay to

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each load of ore. It has been found necessary to add this amount of alumina in order to make poor slags. Nine shovels of the charge are made to one basket of charcoal, containing two bushels and weighing 18.5 pounds. The men employed are the same as in the other furnaces. The casting is done in pigs, which weigh from 50 to 400 pounds, according to their length. The quantity of black copper produced in twenty-four hours is 3500 to 4000 pounds, averaging about 85 per cent. The possible output of each of the two furnaces is from 45 to 60 tons of black copper per month. The matte produced amounts to 3000 pounds, and averages about 55 per cent. This matte forms a thin coating on the top of the black copper, and is easily detached from it by a blow of the hammer. It is called a double or concentrated matte, or sometimes a thin matte. It contains considerable quantities of shot copper, but no attempt is made to separate this. It is not kept by itself, but is charged in the roasting heaps with the other mattes. Pieces of black copper are often attached to it, which are carefully picked out by the men breaking the mattes on the roasting piles.

The shot copper in the sample of which the analysis is given below amounted to 1.04 per cent. When this was carefully sifted out the residue contained:

Copper,	54.93
Iron,	20.66
Sulphur,	23.44
Lead,	0.50
Manganese,	0.06
Lime,	1.01
Magnesia,	0.18

A little lead, only a slight trace of which appeared in the ore, shows itself here.

The black copper contained:

Copper,	94.24
Iron,	3.38
Sulphur,	0.74
Lead,	0.02
Lime,	1.35
	99.73

These pigs are cast in sand, and as soon as cool are broken with sledges to get them into a shape to be easily handled, and to separate

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the mattes, which form a thin film on the top, and are, for this reason, sometimes called thin mattes.

The slags which flow from the furnace are caught in a slag-pot as before. About one hundred such pots are taken from the furnace in twelve hours. The four taken just before casting are always rich. Occasionally a rich tip or knob will be found among the others, but this indicates careless working.

The labor is the same as in all the other furnaces, except the labor of cleaning the pigs.

COST OF SMELTING ROASTED DOUBLE MATTES.

2 Furnace keepers, at $1.00,	$2 00
2 Furnace chargers, at 80 cents,	1 60
2 Slag rollers, at 80 cents,	1 60
Labor per day,	$5 20
Hauling to furnaces, mattes, clay, fluxes, etc., 2 men, 75 cents; 1 horse and cart, 40 cents,	$1 90
	$7 10
Average amount of matte smelted per day, 13½ tons.	
Cost per ton for labor,	52½
" " charcoal, 54½ bushels at 5 cents,	2 72
Cost per ton for labor and fuel,	$3 24½

5. TREATMENT OF THE SALAMANDERS.

All the loupes and salamanders which form in any of the furnaces are treated in the winter season for the copper they contain. They are collected during the rest of the year, and are deposited on the side of the slag heaps. They contain a large amount of copper, and were formerly a source of considerable loss, since all the attempts to treat them as part of the ordinary charge failed. The treatment consists of oxidizing and then sweating them in a German hearth, made by taking out the breast of one of the black-copper furnaces in the upper furnace-house. The furnace is heated with charcoal, and the salamanders piled up against the tuyere side and covered with charcoal, and a powerful blast turned on. This serves to oxidize the iron, and in order to scorify it a little quartz is added. The product is a rich matte, which is treated with the other mattes, and a black copper, which is put with the other black copper. There is about four times as much black copper as mattes. The slags are very rich, and contain at least 1½ per cent. of copper, and are treated

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with the matte in the furnaces. They run out in a stream on the ground. The furnace is charged three times in the twenty-four hours. When the charge is exhausted the matte and pig copper are removed and a new charge put in. The cost in twenty-four hours is, two men at $1 per day, two at 75 cents, and 300 bushels of charcoal. The repairs to tools cost about 25 cents per day. About two tons of salamanders are smelted in this way in twenty-four hours. This work is only done in the winter-time, as the men at any other season would be greatly inconvenienced by the heat. The blast used is at about half a pound pressure.

6. REFINING PIG COPPER.

The refinery furnace, Plate 3, is a reverberatory adapted for wood, and holds a charge of 10,000 pounds. It is thoroughly braced with iron to prevent cracking from expansion. The outside is built of ordinary brick two bricks thick; the inside and roof are made of firebrick. The fireplace is made for wood, and is really a wood gas-producer. It is 4 feet 6 inches long by 4 feet wide. The top of the grate bars is 6 feet 3 inches below the roof, 4 feet 10 inches below the bridge, and 3 feet 8 inches above the ash-pit. They are made of rails supported on two iron supports. The roof of the furnace is continued over the ash pit up to 20 inches from the end wall; from here the fireplace rises 3 feet 8 inches with a width of 20 inches to within 14 inches of the top, where it is narrowed to 14 inches. The total depth of the fireplace above the grate-bars is thus 10 feet. It is covered on the top with a heavy iron door of the whole width of the furnace, counterpoised so as to be raised with the least expenditure of time and force. The fire-bridge is 4 feet 6 inches long and 2 feet 2 inches wide, and 14 inches below the roof. The laboratory is 10 feet long, 4 feet 6 inches at the fire-bridge, and 7 feet in its widest part. The hearth inclines from the bridge on all sides to the working door under the flue, where there is a small sump just large enough to admit of the ladle being put in it to take out the last traces of copper. The height of the roof is uniformly 2 feet 3 inches over the whole surface of the hearth except to within 2 feet of the flue, where it dips to 18 inches at the flue. The flue is 14 inches wide and 4 feet above the level of the working door. The area of the fireplace is 16 square feet, that of the hearth 36 square feet; of the bridge 9 square feet; of the furnace-flue 4 square feet, and that of

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the main flue 8 square feet. Their relative relations are therefore $1 : 2\frac{1}{4} : \frac{3}{4} : \frac{1}{4} : \frac{1}{2}$.

As there is not sufficient pig copper made for continuous running, the furnace is lighted once a week; this is a bad plan, both for the working of the furnace and for the economy of fuel. When cold it must be heated from eight to nine hours to get it into condition to receive the charge. It is besides much more difficult to make good copper on a freshly-heated hearth. It would be much better to allow pig-copper to accumulate until there was enough of it to make a continuous run for some time. This would both improve the quality of the copper and diminish the expense in fuel.

When the furnace is brought to a white heat the hearth is repaired by filling up any cavities that may have formed in it with sand, beating it down, and making the sides and bottom with an even slope towards the sump under the flue. When this has been done the temperature of the furnace is lowered by opening all the doors. When it is reduced to a red heat the pig-copper is charged through the charging door on the side, and so distributed over the hearth that it will be easily reached by the heat. The charging-door is then closed and luted, and the temperature raised to the point of fusion.

It takes four men one hour to charge the furnace. It takes from five to six hours to melt the charge; the first skimming is then made. The analysis of this slag is given (No. 1) in the table below. The charge should be melted slowly in order to get the greatest amount of oxidation at this stage, so that the foreign metals may at once combine with the silica. The slags are not drawn until they cover the whole bath. These slags are pasty, and are drawn off with an iron rabble.

The operation of refining, after the metal is in fusion, consists of three distinct phases, fining, refining, and ladling, the first one of which, the fining, now commences.

The charge, after being crassed, is subjected to a very strong oxidizing atmosphere, in order to slag out the impurities which rise to the surface in the shape of slags and crasses, more or less charged with copper, but all rich, which are carefully put one side, to be treated in the pig-copper fusion. These slags are skimmed as soon as they form in sufficient quantities, and in the intervals the charge is rabbled to make the oxides come to the surface, every twenty-five or thirty minutes, from three to twelve hours, until it boils from the

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evolution of sulphur. This is owing to the fact that it has been impossible to separate all the matte from the pig-copper before it goes into the furnace. It is allowed to boil as long as it will, generally from one to three hours. When it ceases to boil there is no more sulphur present, and it is rabbled from three to five hours, and crassed whenever necessary.

The crasses consist of a very friable material, which contains a considerable amount of metallic copper in the shape of grains. Four samples were taken at the hours indicated in the table. The analyses of these are given below:

ANALYSES OF THE REFINING CRASSES AS A WHOLE.

	No. 1. Six hours after charging.	No. 2. 7 P.M.	No. 3. 2 A.M. boiling ceased.	No. 4. After first poling.
Metallic copper	40.50	26.90	48.50	30.00
Oxide of copper	15.19	12.79	24.45	31.77
Protoxide of iron	26.50	30.88	8.91	19.87
Sulphur	2.77	1.37	0.23	0.11
Alumina	0.66	1.23	0.33	0.68
Manganese	0.06	0.16	0.04	0.06
Lime	1.17	2.70	1.35	2.02
Magnesia	trace.	0.52	0.17	0.31
Cobalt	0.42	1.27	3.88	1.09
Nickel	0.16	1.37	5.36	2.03
Zinc	0.36	0.62	0.00	0.14
Silica	12.72	20.39	6.94	19.94
	100.51	100.20	100.16	98.97
Total metallic copper contained..	54.0	38.26	70.0	58.21

The metallic copper is in grains; the oxide of copper is mostly combined with silica, and partly free as oxide.

MECHANICAL ANALYSIS OF THE REFINING CRASSES.

	1	2	3	4
Metallic copper	40.5	26.9	48.5	30.0
Siftings	59.5	73.1	51.5	70.0

ANALYSES OF THE SIFTINGS.

	No. 1.	No. 2.	No. 3.	No. 4.
Copper	22.67	15.54	42.16	40.30
Iron	34.64	32.85	13.48	12.08
Sulphur	4.66	1.87	0.44	0.16
Alumina	1.11	1.69	0.64	0.90
Manganese	0.10	0.22	0.08	0.08
Lime	1.97	3.70	2.68	2.89
Magnesia	trace	0.71	0.33	0.44
Cobalt	0.71	1.74	7.53	1.56
Nickel	0.27	1.87	10.41	2.90
Zinc	0.60	0.85	0.00	0.20
Silica	21.38	27.89	13.47	28.48

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The copper and iron contained in the above analyses correspond to:

	No. 1.	No. 2.	No. 3.	No. 4.
Oxide of copper Cu_2O, .	25.53	17.50	47.48	45.39
Protoxide of iron, . . .	44.54	42.24	17.31	15.53

The results of these analyses are remarkable. The analysis of the ore, p. 28, showed only from 0.8 to 1.2 per cent. of nickel and cobalt. The ores are thus very poor in these metals. The slags, as a whole, show 0.58 per cent. in slag No. 1; 2.64 per cent. in No. 2; 9.24 per cent. in No. 3; and 3.12 per cent. in No. 4. No. 1 is a bibasic silicate; No. 2 contains a little more silica than No. 1; No. 3 is a tribasic silicate, which contains a little more base than a neutral silicate. They are all lower in silica than is desirable.

The siftings show 0.98 per cent. in No. 1; 3.61 per cent. in No. 2; 17.94 per cent. in No. 3; and 4.46 per cent. in No. 4, which shows that the cobalt and nickel are concentrated in the refining slags continuously up to the point where the sulphur disappears, as shown in No. 3. When the last slags are taken off they are quite poor in cobalt and nickel, and the copper contains no trace of these metals, showing that if the slags were treated as usual, by being put back into the black-copper furnace, the cobalt and nickel would be entirely lost. This fact, so far as I know, has never been noticed before. The amount of the slags taken from the furnace is small, but they should be separated, as the cobalt and nickel are valuable in themselves, and are only impurities in the copper.

When all the slags have been removed the atmosphere of the furnace is still kept oxidizing, in order to remove any trace of impurities except a very small amount of silver and lead. The metal is rabbled and test pieces are taken in order to ascertain its exact quality. As this stage—the taking of tests—is the most important part of the operation, great care was exercised in doing this, and three sets of samples were taken to determine the exact condition of the furnace at these different periods. The analyses of the three sets taken during the rabbling are given below for two sets, and six samples for a third. These all show remarkable freedom from impurities of every kind. The dark-red samples were taken as the rabbling was carried on, from No. 1 to No. 6; the first one after two hours' rabbling, the second after three hours, the third at three and a half hours, and the others from fifteen to thirty minutes each, till the impurities were completely oxidized.

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FIRST SET; DARK-RED SURFACES.

	No. 1. 4 A.M.	No. 2. 5 A.M.	No. 3. 6 A.M.	No. 4. 7 A.M.	No. 5. 8 A.M.	No. 6. 9 A.M.
Oxygen, . . .	1.32	1.21	1.21	1.38	1.28	1.53
Sulphur, . . .	none	none	none	none	none	none
Silver, . . .	0.05	0.05	0.05	0.05	0.05	0.05
Lead, . . .	none	none	none	none	none	none
Copper, by difference,	98.63	98.74	98.74	98.57	98.67	98.42

The second and third sets were taken at much longer intervals; their analyses are given below:

SECOND SET WITH BLACK SURFACES.

	No. 1.	No. 2.	No. 3.
Oxygen, ...	0.34	0.29	0.29
Sulphur, ...	none	none	none
Silver, ...	0 05	0 05	0.05
Lead, ...	none	none	none
Copper, by difference, ...	99 61	99.66	99.66

THIRD SET.

	No. 4.	No. 5.	No. 6.
Oxygen, ...	1.38	1.44	1.52.
Sulphur, ...	none	none	none
Copper, by difference, . . .	98.56	98 50	98.42

The value of silver in all the rabbling samples corresponds to 14.6 ounces to the ton of 2000 pounds.

The operation of rabbling is continued for some time, in order to make sure that all impurities possible shall be separated as oxides, for which reason considerable oxide of copper is formed. This oxide dissolves readily in metallic copper, making the test pieces bright red. When the operation of rabbling is finished this oxide must be separated by a process of refining, for which purpose poling is resorted to. The operation of fining is one of oxidation. As very small percentages of oxide of copper dissolved in metallic copper make it useless for commercial purposes, it must be reduced with the greatest nicety by a carefully conducted process of reduction.

When the assay shows that the impurities are oxidized, the rabbling is discontinued, and the operation of refining, which is one of reduction, is commenced. For this purpose a green or very wet pole is put into the copper and held in it, supported on a wooden crutch; all the airholes of the furnace are stopped tight, and the poling is con-

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tinued until the slag is thick, generally two hours, so it can be skimmed off. The copper is then covered with charcoal and a fresh pole put in about 10 A.M., when samples are taken; the first one half an hour from the time the second poling commenced, beginning at No. 1, and the others during the poling, every 15 or 20 minutes, till the copper is tough pitch, which generally takes about an hour. The samples are bright and shining.

The analyses of two sets of these samples is given below:

FIRST SET.

	1st Poling.	2d Poling.	Casting.
Oxygen,	0.61	0.26	0.24
Copper, by difference,	99.33	99.68	99.70
Silver, one determination for all,			0 06
Lead, " " " "			trace

The silver corresponds to 17.5 ounces to the ton of 2000 pounds.

SECOND SET WITH BLACK SURFACES.

	1st Poling.	2d Poling.	Casting.
Oxygen,	0.20	0.50	0.26
Silver,	0.05	0.05	0.05
Lead,	none	none	none
Copper, by difference,	99.75	99.45	99.69

The silver corresponds to 14.6 ounces to the ton of 2000 pounds.

As soon as the test shows the proper grain and silky lustre the metal is cast into ingot moulds by means of iron ladles covered with a wash of clay in water. These are first put into the furnace to bring them up to the proper temperature, during which time a piece of sheet-iron is put over the door. If put into the copper cold some of the copper would adhere and would have to be detached. After a time the ladles get too hot and are coated with a film of copper. To remove this they are plunged into water. The skull, owing to the wash of clay, is then easily separated. The ladles are recoated with clay. They contain about 1½ ingots of copper, which weigh from 13 to 16 pounds. The ladles last four months; they are then cut off the handles and new ones welded on. The old ladle is worthless as iron, as it contains so much copper. The ladling takes two hours. It is necessary to heat up the furnace at least once during every operation of the casting, when the furnace is out of repair, but when new

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it is not heated after the ladling commences. It takes four men to ladle, two men to tip, and two boys to pick out the ingots from the water-bosh. During the dipping the blacksmith, whose shop is near by, comes to assist.

The man who tips the moulds stands on one side of the water-bosh with an iron rod, with which he picks off from the surface of the melted copper any specks which may float there which would render the ingot imperfect. It is his duty to tip the ingots, as soon as they are sufficiently cool to allow of it, into the water-bosh.

It is essential that the casting should be done at the lowest possible temperature, and that the bath be covered with charcoal. In order to have a reducing atmosphere every precaution should be taken to have a complete combustion of the fuel, and no oxygen in the furnace. This is often not the case, and the copper is frequently cast from under a thick film of oxide of copper.

Seven cords of wood, one-third of which is chestnut, and the rest oak, is used in twenty-four hours.

The refining furnace was in such bad order that the results varied very much. The copper is consequently not of even, though always of high quality, and, as will be seen by the analysis of the ingot copper given below, the copper is often purer at the last stages of poling than in the ingot. That the ingots vary in the amount of oxide they contain could be seen by the eye, but this was owing to the accidentally bad condition of the refining furnace.

The operation of casting or ladling is very difficult, and can only be well done under the very best conditions. As the appearance of the ingot—the heat being uniform, and the copper being good, to commence with—depends on the way it is ladled, pains should be taken not only to drill men for the purpose, but so far as possible to keep the same men at the works. An inexperienced man will splash the copper, which produces inequalities of color on the ingot and bubble-holes. The casting should be made by pouring quietly, so as to produce the least possible motion in the metal, and this should continue until the last drop is out of the ladle. Many of the dippers scatter the last part of the copper, so that it often spatters as a rain into the next moulds.

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COST OF REFINING PIG COPPER,

Produced from Matte Furnace, in Charges of 10,000 *Pounds, yielding* 80 *per cent. Fine Copper.*

Two furnace keepers, at $1.25,	$2 50
Carting, charging, and packing, five men, at 75 cents,	3 75
Fuel used, eight cords of wood, at $1.70 per cord,*	13 60
Fuel used, thirty-three bushels charcoal,†	——
Sand and poles,	25
Cost of labor and fuel, each charge producing 8000 pounds of fine copper,	$20 10
Cost per pound for refining,	25

OTHER DAILY EXPENSES.

One superintendent,	$3 33
One watchman and night-boss,	1 25
One blacksmith,	1 00
Four engineers, at $1.10, each,	4 40
One weighman,	75
One charcoal receiver,	1 54
Two dump men, at 75 cents,	1 50
One stamp man,	75
One carpenter,	1 00
	$15 52
Average amount smelted daily,	50 tons.
Cost per ton for labor, as above,	31 cents.

The cost for soapstone, fire-brick, materials, tools, clay, etc., during fifteen months was $6001.03, or an average cost of 33½ cents per ton.

SUMMARY, COST OF SMELTING PER TON.

Roasting the ore, labor and fuel,	$ 0 18 14/100
Smelting roasted ore, labor and fuel,	8 32
Roasting single and double mattes, labor and fuel,	1 00
Smelting roasted mattes, fuel and labor,	3 24
Refining pig copper: as each ton of the ore yielded 105 pounds fine copper, the cost per ton of ore would be,	26¼
Superintendence and other expenses, as itemized, per ton,	31
Repairs and materials, tools, etc.,	33½

* Wood costs here $1.85 for all selected oak, $1.65 for mixed wood, and $1.50 for soft wood, per cord, and has been averaged at $1.70.

† The charge for charcoal used in refining was included in the average taken of the coal used per ton of ore smelted, and has been charged once against the ore.

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In order to see exactly how the copper compares with other coppers, ingots from Lake Superior and Baltimore were analyzed and tested.

The analyses are given below.

	Ore Knob.	Lake Superior.	Baltimore.
Metallic copper,	99.80	99 830	99.650
Oxygen,	0.39	0.150	none.
Sulphur,	none.	none.	none.
Silver,	0.05	0.026	0.066
Lead,	0 01	0.016	0.044
Arsenic,	none.	none.	0.088
Antimony,	none.	none.	0.035
	100.25	100.022	99.893
Silver, in ounces, to ton of 2000 pounds,	14.6	7 8	19.75

It thus appears that the amount of oxide of copper in the first casting sample was 0 24 per cent.; in the second, 0.26 per cent.; and in the ingot analyzed, 0.39 per cent.; amounts which, although very small, are sufficient to make considerable difference in its value in the arts. The reputation of Lake copper is chiefly owing to the very small quantity of oxide of copper which it contains. The amount of silver is small, and though higher than in the Lake copper, is much lower than in other commercial coppers that I have examined.

The tensile strength of the Ore Knob copper was found to be 30,660 pounds, and that of Lake copper 30,790 pounds to the square inch. The difference is altogether insignificant.

The store yielded a profit of $34,684.60 during the fifteen months ending April 1st, 1880, which, on a product of 17,920 tons of ore treated, reduced the cost of the ore to $1.93½ per ton.

The cost of producing the copper, independent of the store profits, is very low, and this is owing both to the extreme purity of the ore and the very low price of labor and materials.

RÉSUMÉ.

Ore mined, from January 1st, 1879, to April 1st, 1880,	21,223 tons.
Ore smelted, from January 1st, 1879, to April 1st, 1880,	17,920 "
Fine copper produced,	1,640,750 pounds.
Copper matte "	244,325 "
Gross yield,	1,885,075 "

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Fine copper per ton of ore treated, $105\frac{1}{10}$ pounds.

Administration,	$303 33
Dressing,	725 70
Furnace labor,	1828 70
Outside work,—engineers, machinists, and blacksmiths,	568 21
Underground labor,	1631 53
Copper supplies,	45 58
Provender,	646 75
Transportation,	971 00
Miscellaneous,	91 92

Trial balance in 1880, on a run of fifteen months, to April 1st, 1880;

Production,	$202,653 51	
Construction,	2,601 09	
General expenses,	4,703 04	
Total,	$209,957 64	
Cost of copper per pound, from January, 1879, to April, 1880,		12½ cts.*
Profit of store, from January, 1879, to April, 1880,	$34,684 60	
Amount of copper shipped,	1,640,750 lbs.	
Cost of copper per pound, less store profits,		$10\frac{33}{100}$ cts.
Total copper shipped,	1,609,237 lbs.	

TOTAL COST.

DEBIT.		CREDIT.	
Construction and supplies,	$122 88	Store accounts,	$79,264 48
Copper works,	66,443 65	Real estate,	50 00
Labor account,	99,632 47	Live stock,	371 00
Mine supplies,	8,499 24	Balance,	174,478 06
Provender,	5,468 36		
Wood,	11,494 71		
Expense account,	47,703 04		
Transportation,	19,799 24		
Total,	$254,163 54	Total,	$254,163 54

In conclusion, I beg to express my thanks to Mr. J. E. Clayton, the general manager of the works, who gave me every facility to collect information, and prepared himself a number of the tables of cost; and to Captain John Dent, the superintendent of the smelting works, for information given to me at the works and since my return.

* Including all charges, freight, etc.

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Discussion.

In answer to questions Professor Egleston replied as follows:

With regard to the treatment of the iron containing copper, the temperature required for the purpose is so high that the men would hardly be able to endure it in any other season than in the coldest winter weather.

As to the presence of gold in the copper ores of the South I should not like to state it as a rule applicable in every case, but in the instances which have come under my observation the free milling gold ores of the surface have turned into good smelting copper ores containing gold, when they have reached water. There has always been a theory which has been too generally believed, that the gold ores of the South all give out in depth. It is certainly true that they do give out as free milling ores, but I am inclined to believe that they will make good smelting ores below.

The copper ores have not been treated in the wet way of late, because there is too much lime in them. As a general rule the question whether an ore can or cannot be treated comes eventually to a question of transportation. Even with bad roads or high freights a rich ore can be treated by any process, while a poor ore can only be reated by a wet process under the most favorable conditions, when no portion of anything but the available material (which, in this case, would be copper) is attacked by the reagents.

Sulphuric acid has not been made in these works because the gangue of the ore is pyrrhotite and contains too little sulphur, and there is no market for the material that would be manufactured as a by-product. A large district around the works is a desert, for it is impossible to make anything grow on account of the destructive influence of the sulphur in the smoke. Sooner or later this will have to be condensed, and the weak and mother liquors of the acid which will be made, can be used on the poor ores, of which there are from twenty to thirty thousand tons lying broken on the surface, and a very large amount in the mine. This, however, would involve a market for the sulphuric acid, which is out of the question at the present time. The question is an important one, however, for the near future, as the absence of arsenic and antimony in the ore would make the acid salable, if there was only sufficient enterprise to get the transportation, or to manufacture some marketable product which would bear the present or future high rates. With chalcopyrite and pyrites for a gangue, either the one or the other being in large quantity, the acid could be made; but the copper in

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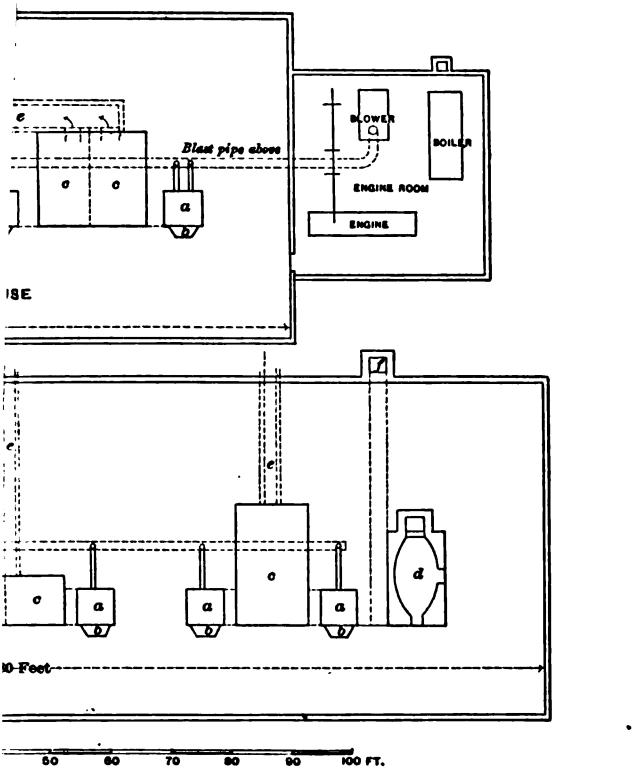
PLATE I.



B COPPER CO., ORE KNOB, N. C.

RUSSELL & STRUTHERS, ENG'S, N. YORK

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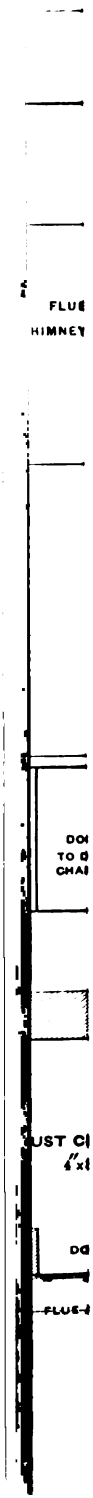
Min



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the residues from the roasting for acid should pay for its own smelting. In some of the southern counties of Virginia the proprietors of some of the mines are now contemplating the erection of large works for the manufacture of sulphuric acid and other chemicals. The whole question, however, is still being studied, and it is a little doubtful whether, even at the low rates at which the pyrrhotite can be mined, it can successfully compete with the imported sulphur.

The main difficulty in the South is the transportation. Many of the railroads have what may be justly called the modern craze of through freights, and do not stimulate or encourage their local traffic. If it were commercially possible to have chemical works in the vicinity of the ores, the proprietors of the copper works could well afford to pay a very considerable percentage more for the roasted copper ores than for the unroasted ones, and would be only too glad to pay the chemical manufacturers a large profit for taking the sulphur out. This establishment of chemical works would solve in certain districts, not only of Virginia, but of other Southern States, the question of the treatment of the poor copper ores which now lie idle. They cannot be concentrated because the difference in density between the pyrrhotite and the chalcopyrite is so small that nothing would result from this treatment. The time must shortly come when wet processes must receive more careful attention in the East. There is, however, a fear that they may receive less, owing to the very large amount of copper ores which are now being found in the western parts of the country.

THE ELECTROLYTIC DETERMINATION OF COPPER, AND THE FORMATION AND COMPOSITION OF SO-CALLED ALLOTROPIC COPPER.

BY J. B. MACKINTOSH, HOBOKEN, N. J.

THE quantitative determination of copper, by means of electro-deposition, offers so many advantages, that it is to be preferred, when properly executed, to all other methods for ease and accuracy. The object of the present paper is to give the results of a number of experiments made during the past few months, and to indicate some sources of error, which must be avoided in order to attain the necessary accuracy.

In 1867, C. Luckow, in competition for a prize offered by the directors of the Mansfield Copper Works, submitted the following

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process for the estimation of copper, and received, not indeed the prize, but an honorable mention for the simplicity, cheapness, and elegance of his process. He directs that the copper and the accompanying metals be obtained in the form of nitrates in solution in dilute nitric acid containing not more than 0.100 gram of the pure acid in each cubic centimeter; to this solution is added a few drops of a solution of an organic acid, such as tartaric or oxalic, and the copper is then precipitated on platinum in the usual manner. It is claimed that the copper is obtained in beautiful reguline form, while zinc, iron, and nickel are not precipitated at all.

In adapting this method to the analysis of copper alloys, I dissolved the alloy in nitric acid, evaporated the solution to dryness to get rid of the excess of acid, dissolved the residue in water with the addition of a few drops of nitric acid, to dissolve the basic nitrate of copper formed, and to this solution added four or five drops of a concentrated solution of citric acid. This solution was then precipitated in a platinum dish with a current from two Bunsen cells of about one quart capacity. In precipitating several samples at once, I have it arranged so that the whole current traverses the row of dishes, the negative pole of each set being connected with the positive pole of the next succeeding one. In this case if n be the number of dishes, then $n+1$ is the number of battery-cells of that size used.

Some of the results obtained by this method, and on duplicate portions by precipitation from sulphuric acid solution, are as follows:

	Sulphuric Acid.	Nitric+Citric Acid.	Error.
1 gram pig copper,	98.00	99.42	+1 42
" "	99 80	101.22	+1.42
" "	93.92	100.41	+1.49
" "	98.72	100.27	+1.55
" "	99.60	100.45	+0.85
1 gram brass,	65 83	66 93	+1.10
" "	65.83	66.58	+0 75

In only one case was a smaller percentage obtained by the use of this method, and in that case the precipitation of the copper was not complete. In many cases, also, in which the amount of error was less than one per cent., small quantities of copper escaped precipitation and were afterwards found in the solution.

The metallic precipitate thus produced is of a much lighter color than ordinary copper from the electrolysis of the sulphate solution, but it is, as Luckow says, deposited in beautiful reguline form, which, however, hardly compensates for the error of perhaps one per cent. or more, which we see is, as a general rule, the case.

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Moreover, if the current is strong, after all the copper has been thrown down, zinc will be deposited on the surface of the copper, as a dark coating, which may be recognized as such by dissolving in dilute sulphuric acid and applying appropriate tests.

In the presence of the organic acid the formation of peroxide of lead on the positive pole is hindered, and in its absence it is very difficult to precipitate the whole of the copper from the solution.

In order to obtain sufficient material for analysis, to ascertain the cause of the excess in weight, the precipitation of the copper was made on a piece of platinum foil. On attempting to strip the deposit from the foil, I found that it was extremely brittle, and scaled off easily; so brittle, indeed, that it could be reduced to an impalpable powder in an agate mortar with very little trouble. This agrees exactly with the description of the allotropic copper of M. P. Schutzenberger, which was published in *Comptes Rendus*, Vol. 86, part 2. M. Schutzenberger obtained the material he describes by the electrolysis of a ten per cent. solution of the neutral acetate of copper. He found that the product contained from five to ten per cent. of suboxide of copper. In the material which I prepared from the nitric and citric acid solution, I did not find any suboxide of copper; on the other hand, both carbon and hydrogen have been detected and estimated. These latter were determined by combustion of the finely divided sample in oxygen; the method used to estimate the suboxide of copper was that of Hampe.* However, oxygen is present, though as this test shows, not as cuprous oxide.

The results of the analyses of several samples, prepared at different times, are given below. The determinations were all made on the amount of one gram:

	a	b	c	d	e	f	g	h
Carbonic acid	.0273	.0316	.0350	.0344	.0322	.0324	.0346	.0283
Equivalent to carbon	**.00744**	**.00862**	**.00954**	**.00938**	**.0088**	**.0088**	**.0094**	**.00771**
Water	.0094	.0108	.0089	.0094	.0054	.0045	.0074	.0054
Equivalent to hydrogen	**.00104**	**.00120**	**.00100**	**.00104**	**.0006**	**.0005**	**.00082**	**.0006**
Ratio of carbon to hydrogen	7.15	7.18	9.54	9.0	14.6	17.6	11.46	12.42
Copper			**.9683**	**.9687**				
Total			**.97884**	**.97912**				

* Zeitschrift für Analytische Chemie, 1878, p 127.

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The results which are bracketed are from duplicate analyses. These samples were all prepared from the nitric and citric acid solution. *a*, *b*, and *c d* were prepared simultaneously, the solution of *b* containing a little more citric acid than that of *a*, and *c d* more than either. The samples *e*, *f*, *g*, and *h* were heated to about 100° C. for fifteen minutes before being introduced into the combustion-tube, and the samples *c*, *d*, *e*, and *f* were the same. The results given under *h* are low, probably due to imperfect oxidation.

It will be seen that there is a deficiency of .02116 and .02088 respectively in the total of the duplicate analyses *c* and *d*. The precaution was taken in one case, of passing the products of the combustion over a red-hot layer of oxide of copper, to make sure that no hydrocarbon was distilled out by the gradually increasing heat and so escaped oxidation. The results in this case, however, differed in no material manner from those already obtained. We conclude therefore, that this deficiency must consist either of *oxygen* or *nitrogen*, or of a mixture of both. I have already mentioned that there is no oxygen in the form of cuprous oxide present, so that it must, if present, be combined in some other form. The following synthetical experiments seemed to indicate that *nitrogen* was also an essential constituent.

These experiments were conducted as follows: Solutions were prepared of nitrate and of sulphate of copper; to these solutions were added respectively, citric acid, tartaric acid, and alcohol. All three of the solutions of the nitrate furnished the brittle deposit, while all three of the sulphate solutions gave a tough deposit of apparently ordinary electrotype copper. The amount of copper was determined in 1.0008 grams of the precipitate from the sulphate solution containing acohol, and found to be 0.9991. This difference is probably due to impurities in the copper, which was prepared in the first place from the commercial sulphate, which contained lead and other impurities.

During the electrolysis of the nitrate solutions containing citric acid, a very strong odor of hydrocyanic acid was perceptible.

If an insufficient amount of organic matter be added, the precipitated copper obtained is not brittle, but it nevertheless contains carbon and hydrogen and gives a total result less than 100 per cent. This is due to admixture of ordinary copper. It is not possible to divide such a precipitate sufficiently finely to insure perfect oxidation.

The amount of nitrogen present in the nitric-citric precipitated copper, was determined by heating the finely pulverized sample in a vacuum and collecting the gases evolved. The products thus ob-

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tained were hydrogen, carbonic acid, and nitrogen. When heated in an atmosphere of oxygen, insufficient to completely oxidize the copper, the products were water, carbonic acid, and nitrogen. Although in this case it was probable that an excess of oxygen would be present, yet the analytical results showed the absence of that gas in any appreciable quantity.

The volumes given are those of the dry gas at 0° C. and 760 mm.

1 gram heated in Vacuo.		½ gram in Oxygen.	1.15 gram in Oxygen.
Gas obtained,	9 95 c.c.	8.23 c.c.	17.52 c.c.
CO_2 absorbed by KOH,	4 72 "	7.35 "	15.70 "
Gas not CO_2,	5.23 "	0.88 "	1.82 "
Oxygen added,	7.77 "	These residues treated with moist phosphorus to absorb oxygen, and then with KOH, did not change, proving the absence of oxygen.	
	13.00 "		
Volume after explosion,	7.44 "		
Loss—Water,	5.56 "	The circumstances of formation were such as to preclude the existence of hydrogen, therefore these residues must be nitrogen.	
No CO_2 formed: *Hydrogen*,	3.71 "		
Residue: *Nitrogen*,	1.52 "		

The percentage results in the foregoing three cases are respectively for nitrogen: 0.191, 0.221, 0.199; and in the two last for carbon: 0.792, 0.736; the ratio of $\frac{C}{N}$ being 3.6 and 3.7.

One sample of the product, made with tartaric acid, weighing two grams, was also analyzed for nitrogen, and one cubic centimeter of dry nitrogen at 0° C. and 760 mm. obtained. It is difficult when working on such small quantities of gas, to obtain very accurate results.

Some of the allotropic copper prepared from the chemically pure acetate, according to M. Schutzenberger's directions, and which therefore could not contain nitrogen, and also some prepared from an acetate of copper containing nitrate of soda, were compared and analyzed. The material thus obtained was apparently the same in both cases, and differed considerably in some of its properties from the nitric-citric acid solution precipitate. In appearance, brittleness, and composition there was no essential difference, but it was very unstable and liable to oxidize, in fact, it was not possible to preserve it of constant composition in the air, while the nitric-citric precipitate can be preserved indefinitely without change.

Two samples of 1.0014 and 1.0004 grams respectively were weighed out. The first was heated for about fifteen minutes to 100° C. in an air-bath; on cooling and weighing it had gained 0.0215 gram. The second sample was exposed to the air at the ordinary temperature for two hours and three-quarters, at the end of that

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time it had gained 0.0225 gram; it was then heated to 100° C. for fifteen minutes, when it lost 0.0020 gram, giving a net gain of 0.0205 gram.

The amounts of carbon and hydrogen were determined in the second sample of the material from the acetate solution containing nitrate of soda, and in two samples from the chemically pure acetate preparation.

	$Cu(C_2H_3O_2)_2$ + $NaNO_3$	$Cu(C_2H_3O_2)_2$	
Amount taken,	1.004 gram.*	1 gram.	1 gram.
CO_2 found	.0145	.0175	.0164
Equivalent to C,	.00395	.00477	.0042
H_2O found	.0081	.0092	.0081
Equivalent to H,	.0009	.00102	.0009
Ratio, C:H,	4.4	4.676	4.666

The cause of the rapid oxidation of these samples seems to be that the deposit is very porous, while that from nitric solutions is very dense.

M. Schutzenberger mentions that he had at one time a considerable quantity of this allotropic copper (*sic*) reduced to powder and dried in a vacuum, which at the moment when air was admitted to it, was transformed to ordinary copper, attended by a considerable evolution of heat. The amount of oxygen he found was not altered by this occurrence.

To account for this phenomenon he frames the theory that the allotropic copper corresponds to cuprous copper, and that the molecular change to cupric copper is accompanied by the development of heat. But we can easily see how liable to spontaneous oxidation a large quantity of such finely divided material would be, when it contains both carbon and hydrogen in a weak state of combination, and it is unnecessary to suppose the existence of another form of metallic copper to account for the phenomena noticed.

The practical conclusions to be drawn from these results are, that some organic matters, and in all probability all, in the presence of nitric acid in the copper solution undergoing electrolysis, cause erroneous results; that from a nitric acid solution, with no organic matter, it is extremely difficult to separate all the copper; and that the old method of electrolysis from the sulphate is the best.

Discussion.

Dr. Egleston, New York: The paper which I have just read is one of great interest. It represents the work of my assistant, who

* Oxidized by exposure to air and heating in air-bath before combustion.

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is a man of great skill in this particular line of his profession, for nearly a year in my laboratory. There will certainly be in this connection two subjects which must come up for discussion in the Institute before a great while, and these are "what is copper?" and "what copper is," and which will have, in a commercial point of view, as great or even greater interest than the similar discussion which took place a few years ago about steel. What is sold in the market as copper may contain anywhere from one-tenth to one per cent. of foreign material. Out of a very large number of analyses of the ordinary commercial coppers, the best sample that we were able to get contained only 99.91 per cent. of copper. This is much more important than it would at first sight appear to be, because there is a direct relation between the purity of the copper and its electrical conductivity. The presence of so small a quantity as nine-hundredths of a per cent. of foreign matter may be sufficient to take away more than ten per cent. of the conducting power of the material. The manufacture of pure copper for the application of electricity to the industrial arts, which will in a few years be one of the greatest commercial questions to be solved, is therefore much more important than is generally supposed. This is not only true of copper, but of its alloys. Certain alloys made from metals of high quality have become of great commercial importance within a few years; but great difficulty has been experienced in manufacturing them, for while some of the alloys do not stand the test and are therefore rejected at once, others will stand it for a few weeks or months, and will then become brittle and worthless. I hope, therefore, that this matter will receive from the chemists of the country the careful attention which it deserves.

The paper of Mr. Mackintosh is the result of analyses of over seventy samples of copper and brass from different parts of this country in all stages of their manufacture. There are many samples of copper in which less than one-half of one per cent. of foreign material has made the copper perfectly worthless for certain large industrial applications, and it requires but an extremely small amount to render it worthless for processes of conductivity. A change takes place in the alloys of copper which is partly physical and partly chemical, which may render the alloy useless after a certain time, although it may satisfactorily undergo all the tests immediately after its manufacture. In view of the very small quantities of foreign matter which make the changes in copper, the question which Mr. Mackintosh has brought before the Institute is one of very great importance.

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Whatever may be the method which is used for analyzing copper, there is one thing which must be very carefully taken into account, and that is the influence of organic matter in solution. It makes no difference what the method is, if organic matter of any kind gets into the solution the analysis of the copper will be likely to be incorrect.

I have seen very large works make the determination of copper in porcelain vessels with platinum strips. We have found that under such circumstances it is impossible to get accurate results, for if even very small quantities of copper become detached from the strips and fall upon the porcelain the copper is in danger of oxidation. Mr. Mackintosh has devised a very ingenious arrangement of copper wires switching into mercury, by which the whole current of the battery passes under a number of dishes, equally divided amongst them all, and if there is any necessity for so doing, he can switch out one or two vessels and pass the current through the remainder. This system has been in use in my laboratory for over two years, and has worked most satisfactorily; it is so arranged that each platinum dish rests upon a metallic support, which passes underneath the vessels, and is connected with the battery by means of thumb-screws and wires.

Extremely minute amounts of cobalt, nickel, oxide of copper, and zinc will reduce the conductivity of the copper wire very largely. In fact, almost everything except silver which may be contained in the copper will reduce it. In the case of iron I had occasion recently to ascertain that oxide of iron, which is generally neglected in the analysis of iron wires used for electrical purposes, is one of the most deleterious materials ever found in it.

The experiments which I have been making during the last year have been on wires having different mechanical and chemical composition; and in order to be certain of the results, we have gone so far as to solder wires together, some of which were afterwards drawn down, and others tested without being drawn, but no appreciable difference was found. Oxide of iron is certainly not evenly distributed throughout the mass, and causes the fibres to separate in such a way, both in the interior and the exterior of the rod, that this want of homogeneity may possibly have as direct an influence as that of the presence of an alloyed impurity. There is no doubt whatever about the effect of cobalt, nickel, and zinc. A series of experiments were made by the first cable company as to their effect, which have been fully confirmed by my analyses and experiments during the last year. The presence of silver would have the effect

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of raising the conductivity even in the presence of nickel and cobalt, since its conducting power is much higher than that of copper.

S. P. SHARPLES, Boston: If there is any one metal which has interested me more than another during the last fifteen years that metal has been copper. While I was a student in the Lawrence Scientific School under Dr. Wolcott Gibbs, during the winter of 1866–7, he called my attention to some analyses that were made by Mr. E. V. McCandless, in the laboratory of the school. These analyses were published in the *American Journal of Science and Arts*, January, 1865, the paper bearing date, October 1st, 1864. He found that he could completely precipitate copper from a sulphuric acid solution, using a platinum plate for the positive and a platinum dish for the negative electrode. The copper after precipitation was carefully washed with distilled water and dried in vacuo over sulphuric acid.

Dr. Gibbs suggested that I should take some pure copper and dissolve it in sulphuric acid with the addition of some nitric acid, and then evaporate to dryness over a lamp so as to expel the nitric acid and the excess of sulphuric acid, and then precipitate and weigh. After weighing the copper was again dissolved in the same dish and again evaporated to drive off excess of acid, dissolved in water, precipitated again and weighed. This operation was repeated several times with closely agreeing results, thus confirming Mr. McCandless's work. The paper by Dr. Gibbs was published in German in *Fresenius Zeitschrift für Analytische Chemie*, Vol. 3, 1864. In Volume 8 of the same journal is a long paper by C. Luckow, in which he says he had first described this method in Dingler's Journal in 1866, or a year after it was described by Dr. Gibbs. I have been particular in regard to dates, because this method, or some trifling modification of it, is republished every few years as something new.

I have made many hundreds of determinations of copper by this method with uniformly good results. In the course of this work I have found that many of the precautions that we originally considered necessary may be omitted. In the first place a little nitric acid in the solution does no harm; the evaporating to dryness is time wasted. Care should be taken, however, not to have too great an excess of acid of any kind present. If from any cause we find that too much free acid is present in the solution, it can be readily neutralized by the addition of a little ammonia water, not quite sufficient to neutralize the acid. The drying in vacuo is also unnecessary. Dr. Gibbs suggested that the water be removed by a

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little alcohol, as this would evaporate in less time than water. This was tried with satisfactory results. The next suggestion (whose I know not) was that the alcohol might be burnt off; this also works well.

The process of analysis which has been followed in my laboratory since 1871 is as follows, and it is just the same whether the substance be a matte, an alloy which does not contain metals thrown down by the battery in an acid solution, or an ore: Two grams of the substance, if it contains more than ten per cent. of copper, or four or five if it is poor in copper, are weighed into a porcelain dish. This is treated with 5 c.c. of strong sulphuric acid, then a little nitric acid is added from time to time until the action ceases. It is then heated to boiling over a lamp, allowed to cool and diluted to about 50 c.c., boiled and filtered. If the substance is well ground, a single treatment is generally sufficient; if, however, any black residue remains, this treatment is repeated. If there is any lead in the ore it is converted into a sulphate, and remains behind on the filter; the trace that goes through may be neglected, since it is not precipitated with the copper. The copper solution is filtered directly into the platinum dish, which should hold about 200 c.c., though with care one holding 100 c.c. can be used.

This operation generally is completed in half an hour from the time the ore is weighed. The precipitation takes care of itself; the dish being placed in the circuit when the laboratory is left in the evening, in the morning we find the work finished. The solution is tested by taking out a drop and putting it on a white plate with a drop of hydric sulphide; if the copper is completely precipitated the dish is removed from the battery, the solution poured out and saved if necessary for the determination of other substances. The dish is then washed with pure water, followed by alcohol; the alcohol is then drained out as completely as possible, and the little that adheres to the dish set fire to. This operation not only serves to dry the copper, but it also prevents the oxidation during the drying. A very slight bluing of the copper does no harm, as it will not perceptibly change the weight. The whole operation, from the time the precipitation is complete until the copper is weighed, need not take more than ten minutes.

Within a few months I have had occasion to test the method very carefully. Certain parties were dissatisfied with my results, which they claimed were too high, and demanded my samples. The samples had already been sent to an eminent chemist, who returned them to me with his method of analysis. His results were about one-tenth of a per cent. higher than mine, while the method em-

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ployed by him involved about five times the work. I have had no further advices from the dissatisfied parties, though they have had the samples for two or three months. This method bids fair to become the standard method of copper determination in this country. I know of some heavy contracts in which it has been inserted as part of the agreement.

In connecting the precipitating dish with the battery, I find it is better, when more than one dish is used, to connect the positive pole of the battery with a sheet of metal or wire on which both of the dishes are set, and to connect the platinum strips with the wire proceeding from the other pole of the battery. In this way the current is divided between the cells, and the resistance is less than if the cells are in series. I find that two small Grove cells are sufficient for the purpose.

The commercial allowance for variations in analyses of copper ores is one-half of one per cent.; the actual variation on analyses made by this method in duplicate does not often exceed one-tenth of one per cent.

AN ANALYSIS OF THE CASUALTIES IN THE ANTHRACITE COAL MINES, FROM 1871 *TO* 1880.

BY H. M. CHANCE, M.D., ASST. GEOLOGIST, PENNSYLVANIA GEOLOGICAL SURVEY, PHILADELPHIA.

THE following tables have been compiled from the annual reports of the Inspectors of Mines, to determine the percentages of fatal and non-fatal casualties from roof-falls and explosions of fire-damp.

As we cannot assume that every accident has been recorded by the inspectors; as many casualties terminating fatally after the lapse of a considerable period, are inevitably recorded as "non-fatal;" and as clerical errors may have crept into the compilation,* the figures of these tables cannot be considered absolutely correct, but the summary is sufficiently reliable to show the features I wish to differentiate.

Under the heading "Miscellaneous" are included all accidents not directly attributable to explosions of fire-damp, roof-falls or falls of coal. Prominent among the numerous causes included under this head are premature or delayed explosion of blasts, accidental explosion of powder or cartridges, accidents from mine cars, falls in shafts, machine accidents, sliding of loose coal in pitching breasts, suffocation by choke-damp, etc., comprising in all 48 per cent. of the total number of casualties.

* Compiled by Mr. Maxwell Chapman.

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Falls of coal, though not properly belonging to the same class of casualties with roof-falls, have been included under this head. The general summary shows that 36 per cent. of the total number of casualties are directly traceable to falls of roof and coal, this percentage constituting 44 per cent. of the fatal and 32 per cent. of the non-fatal accidents; or in numbers, there were 890 fatal and 1620 non-fatal accidents from this cause in the nine years, from 1871 to 1879, inclusive.

In 1864 the accidents attributable to this class in the coal-fields of Great Britain reached 45 per cent. of the total number of casualties.

Roof-falls are common to all mines and cannot be entirely avoided, even if the greatest precautions are taken; but they are especially occasioned by *thick seams*, by clods of shale or rock loosely adhering to the roof, and, when the roof is fair, by *inattention to the proper placing and renewal of props*, by badly located *shots spending their force upon the roof*, by the *vibration caused by shots* fired in adjoining or distant workings, by *driving breasts too wide*, by improper *removal* of *props*, and by *explosions of gas*. Falls of coal are similarly occasioned, but are most frequently the result of improper underholing or taking-up of bottom coal, allowing too large a mass of unsupported coal above the miner.

The majority of casualties from roof-falls, and nearly all those from falls of coal, occur at or near the working face, and are directly attributable to the carelessness or poor judgment of the miner, or to his reluctance to take the proper precautions and exercise the proper care, because these involve some additional labor and trouble for which he will receive no pecuniary reward.

An extremely dangerous roof is occasionally met with,—notably at Pittston, where it is locally called the "black rock," etc. It is a dark carbonaceous slaty shale, perfectly hard and firm when first exposed, but it soon swells and softens from exposure to the atmosphere, and breaks off in large masses. A shale roof is seldom safe, but is particularly dangerous when but a few feet in thickness and loosely adhering to a firm sandstone roof, or if irregularly bedded in lens-shaped masses or fissured by cleavage joints. A large mass of such material may hang for a long period, sustained by its adhesion to the firm sand-rock above, only to fall without warning when this adhesion is lessened by exposure to the atmosphere, or from the vibrations caused by the firing of shots.*

* See reports of the Inspectors of Mines, 1878. p. 209, and 1879, p. 301, for illustrated examples of accidents resulting from similar conditions.

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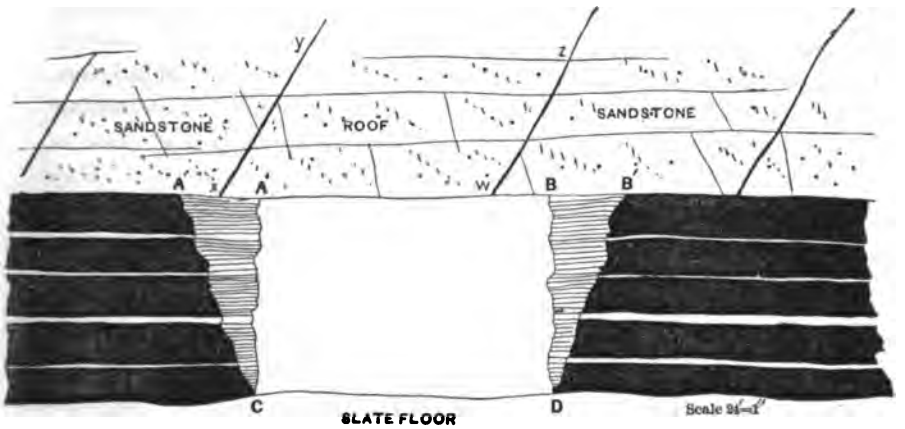
When the roof is in fair condition, falls are often occasioned by driving the working places too wide, or if they have originally been of proper width, by "skipping" the pillars, or by the pillar coal spalling off in wedge-shaped masses as shown by the accompanying sketch.

The breast originally driven as indicated by the lines *A C* and *B D* becomes enlarged after a time to the size *A' B' D C* by the wedge-shaped masses *A C A'* and *B D B'* breaking off. If these do not actually drop off, the lines of fracture *A' C* and *B' D* practically increase the distance between supports from *A B* to *A' B'*, greatly increasing the danger from roof-falls, for a roof perfectly safe when supported at *A* and *B* may be very unsafe when these supports are removed to *A'* and *B'*. The figure shows two cleavage planes *xy* and *wz* in the sandstone roof, which will allow a large mass to drop when the support is removed from *A*.

FIG. 1.



SECTION ACROSS OLD BREAST

Attention to the proper placing, renewal, and removal of props is of prime importance, and a systematic and periodical inspection of the roof in all travelling ways and working places cannot be too strongly urged. This inspection should be intrusted to a thoroughly competent, experienced, and intelligent man only, invested with the necessary authority to enforce his orders, and who should be held personally responsible for all such casualties occurring within his jurisdiction. I venture to suggest this as a means of decreasing the number of casualties from roof-falls, feeling that in this respect nothing can be expected from the miner himself.

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When the roof is not known to be perfectly secure, mining should certainly be suspended, and the men removed to a safe retreat during the firing of shots in adjoining and even distant working places, to avoid the risk occasioned by the vibrations of the roof.

The tables show a total number of 2510 casualties resulting from falls of roof and coal; it would be interesting and instructive to know how many of these could have been avoided, had proper precautions been taken. This is a matter beyond the control of the mine inspector; his visits are necessarily made at considerable intervals, and although he may often be enabled to greatly diminish the danger from this cause, by ordering additional propping, etc., he cannot enforce the constant watchfulness and care necessary in every mine where the roof is unsafe. I am convinced that a large majority of these accidents are due to criminal carelessness on the part of the miner himself, to the recklessness that comes to all men inured to danger, and to the disinclination so frequently exhibited to undertake any additional labor that does not offer an immediate and positive remuneration.

The casualties from explosions of gas number 1127,—16 per cent. of the total number,—of which 225 resulted fatally. The number of recorded explosions from 1870 to 1880 inclusive, is 639.

In a paper read before the American Philosophical Society, May 6th, 1881, I have shown that 463 of these occurred from April to October, and the remaining 216 during the winter months, November to March inclusive. The table is as follows:

Explosions of Fire-damp, 1870 to 1880.

January,	36	August,	64
February,	36	September,	66
March,	34	October,	72
April,	65	November,	52
May,	79	December,	58
June,	61		
July,	56	Total,	679

This shows an average of 66 per month for the warm months, April to October inclusive, and an average of but 43 for the remaining (cold) months of the year, and certainly seems to point primarily to an impairment of ventilation from high temperature as the cause of the greater number of explosions during the warmer months.

The accidents included under the head "Miscellaneous" embrace 48 per cent. of the total number of casualties, aggregating in all 3403 of which 916 resulted fatally.

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The total number of casualties recorded by the inspectors for the nine years is 7040, of which 2031, or about 29 per cent., resulted fatally.

The "summary of percentages,"—Table XI*a*,—develops a remarkably uniform relation between the relative number of accidents attributable to roof-falls, explosions, and other causes, and also between the percentages of those terminating fatally each year. This is also evident in Tables XII and XII*a*.

TABLE I.

Fatal Accidents in 1871.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	4	14	12	30
Ashland "	20	2	34	56
Shamokin "	18	9	16	43
Southern "	12	0	16	28
Middle "	15	1	37	53
	69	26	115	210

TABLE I*a*.

Non-fatal Accidents in 1871.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	*84	*98	*115	118
Ashland "				168
Shamokin "				120
Southern "	17	1	18	36
Middle "	27	31	32	90
	†144	†149	†239	532

TABLE II.

Fatal Accidents in 1872.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	36	14	41	91
Ashland "				
Shamokin "				
Southern "	13	1	11	25
Middle "	15	8	17	40
Eastern "	36	5	26	67
	100	28	95	223

* January 1st to October 15th. † Totals only approximately correct.

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TABLE IIa.

Non-fatal Accidents in 1872.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District, Ashland " Shamokin "	68	103	99	265
Southern "	10	5	23	38
Middle "	33	24	64	121
Eastern "	68	24	95	187
	111	53	182	346

TABLE III.

Fatal Accidents in 1873.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District, Ashland " Shamokin "	52	23	51	126
Southern "	21	1	16	38
Middle "	11	6	29	46
Eastern "	32	3	19	54
	116	33	115	264

TABLE IIIa.

Non-fatal Accidents in 1873.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District, Ashland " Shamokin "	90	77	212	379
Southern "	12	2	32	46
Middle "	21	14	56	91
Eastern "	77	19	73	169
	200	112	373	685

TABLE IV.

Fatal Accidents in 1874.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	5	13	17	35
Ashland "	20	3	21	44
Shamokin "	13	1	12	26
Southern* "				
Middle "	17	9	31	57
Eastern "	39	1	29	69
	94	27	110	231

* No report from this district in 1874.

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TABLE IV*a*.

Non-fatal Accidents in 1874.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	22	38	40	100
Ashland "	32	7	56	95
Shamokin "	59	20	71	150
Southern* "				
Middle "	25	32	48	105
Eastern "	35	10	44	89
	178	107	259	539

TABLE V.

Fatal Accidents in 1875.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	11	7	10	28
Ashland "	11	0	15	26
Shamokin "	16	0	22	38
Southern "	11	2	8	21
Middle "	19	6	38	63
Eastern "	29	3	40	72
	97	18	133	248

TABLE V*a*.

Non-fatal Accidents in 1875.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	17	28	43	88
Ashland "	50	15	49	114
Shamokin "	60	3	45	108
Southern "	41	3	33	77
Middle "	20	32	48	100
Eastern "	21	1	80	102
	209	82	298	589

TABLE VI.

Fatal Accidents in 1876.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	5	10	13	28
Ashland "	9	1	17	27
Shamokin "	14	1	22	37
Southern "	18	4	15	37
Middle "	23	7	15	45
Eastern "	20	6	18	44
	89	29	100	218

* No report from this district in 1874.

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TABLE VI*a*.

Non-fatal Accidents in 1876.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	19	34	13	66
Ashland "	14	9	25	48
Shamokin "	21	13	27	61
Southern "	28	17	29	74
Middle "	18	22	47	87
Eastern "	44	21	55	120
	144	116	196	456

TABLE VII.

Fatal Accidents in 1877.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	5	10	12	27
Ashland "	20	0	9	29
Shamokin "	17	0	11	28
Southern "	17	0	9	26
Middle "	25	1	12	38
Eastern "	31	1	8	40
	115	12	61	188

TABLE VII*a*.

Non-fatal Accidents in 1877.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	21	44	24	89
Ashland "	27	7	24	58
Shamokin "	31	7	28	66
Southern "	20	9	31	61
Middle "	34	24	63	121
Eastern "	64	28	82	174
	197	119	252	568

TABLE VIII.

Fatal Accidents in 1878.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	5	3	6	14
Ashland "	13	0	13	26
Shamokin "	16	11	20	47
Southern "	15	2	13	30
Middle "	14	7	15	36
Eastern "	16	0	18	34
	79	23	85	187

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TABLE VIII*a*.

Non-fatal Accidents in 1878.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	4	11	15	30
Ashland "	40	7	42	89
Shamokin "	44	12	71	127
Southern "	43	2	25	70
Middle "	34	2	63	99
Eastern "	34	0	54	88
	199	34	270	503

TABLE IX.

Fatal Accidents in 1879.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	10	5	9	24
Ashland "	21	3	19	43
Shamokin "	25	4	17	46
Southern "	15	2	8	25
Middle "	30	12	23	65
Eastern "	30	3	26	59
	131	29	102	262

TABLE IX*a*.

Non-fatal Accidents in 1879.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
Pottsville District,	45	35	78	158
Ashland "	40	18	53	111
Shamokin "	22	15	66	103
Southern "	44	8	48	100
Middle "	53	45	87	185
Eastern "	39	9	86	134
	243	130	418	791

TABLE X.

Fatal Accidents, 1871 *to* 1879.

Years.	Roof-falls.	Explosions.	Miscellaneous.	Total.
1871,	69	26	115	210
1872,	100	28	95	223
1873,	116	33	115	264
1874,	94	27	110	231
1875,	97	18	133	248
1876,	89	29	100	218
1877,	115	12	61	188
1878,	79	28	85	187
1879,	131	29	102	262
1871 to 1879,	890	225	916	2031

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TABLE Xa.

Non-fatal Accidents, 1871 *to* 1879.

Years.	Roof-falls.	Explosions.	Miscellaneous.	Total.
1871,	144	149	239	532
1872,	111	53	182	346
1873,	200	112	373	685
1874,	173	107	259	539
1875,	209	82	298	589
1876,	144	116	196	456
1877,	197	119	252	468
1878,	199	84	270	503
1879,	243	130	418	791
1871 to 1879,	1620	902	2487	5009

TABLE XI.

General Summary, 1871 *to* 1879.

Years.	Roof-falls.	Explosions.	Miscellaneous.	Total.
1871,	218	175	354	742
1872,	211	81	277	569
1873,	316	145	488	949
1874,	267	134	369	770
1875,	306	100	431	837
1876,	233	145	296	674
1877,	312	131	313	756
1878,	278	57	355	690
1879,	374	159	520	1053
1871 to 1879,	2510	1127	3403	7040

TABLE XIa.

Summary showing Percentages.

	Roof-falls. Fatal.	Non-fatal.	Explosions. Fatal.	Non-fatal.	Miscellaneous. Fatal.	Non-fatal.	Total.
1871,	.10	+ .19 = (.29)	.03	+ .20 = (.23)	.16	+ .32 = (.48)	= 100 per cent.
1872,	.17	+ .20 = (.37)	.05	+ .09 = (.14)	.16	+ .33 = (.49)	= 100 "
1873,	.12	+ .21 = (.33)	.03	+ .13 = (.16)	.12	+ .39 = (.51)	= 100 "
1874,	.12	+ .23 = (.35)	.03	+ .14 = (.17)	.14	+ .34 = (.48)	= 100 "
1875,	.11	+ .26 = (.37)	.02	+ .10 = (.12)	.16	+ .35 = (.51)	= 100 "
1876,	.13	+ .21 = (.34)	.04	+ .18 = (.22)	.15	+ .29 = (.44)	= 100 "
1877,	.15	+ .26 = (.41)	.02	+ .16 = (.18)	.08	+ .33 = (.41)	= 100 "
1878,	.11	+ .29 = (.40)	.03	+ .09 = (.12)	.13	+ .38 = (.51)	= 100 "
1879,	.12	+ .23 = (.35)	.03	+ .13 = (.16)	.10	+ .39 = (.49)	= 100 "
1871–1879,	.12	+ .24 = (.36)	.03	+ .13 = (.16)	.13	+ .35 = (.48)	= 100 "

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TABLE XII.

Summary showing Percentages,—Fatal Accidents.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
1871, . . .	.33	.12	.55	100 per cent.
1872, . . .	.45	.13	.42	"
1873, . . .	.44	.12	.44	"
1874, . . .	.41	.12	.47	"
1875, . . .	.39	.07	.54	"
1876, . . .	.41	.13	.46	"
1877, . . .	.61	.06	.33	"
1878, . . .	.42	.13	.45	"
1879, . . .	.50	.11	.39	"
1871 to 1879, . .	.44	.11	.45	100 "

TABLE XIIa.

Summary showing Percentages,—Non-fatal Accidents.

	Roof-falls.	Explosions.	Miscellaneous.	Total.
1871, . . .	.27	.28	.45	100 per cent.
1872, . . .	.32	.16	.52	"
1873, . . .	.29	.17	.54	"
1874, . . .	.32	.20	.48	"
1875, . . .	.36	.14	.50	"
1876, . . .	.31	.26	.43	"
1877, . . .	.35	.21	.44	"
1878, . . .	.40	.07	.53	"
1879, . . .	.31	.16	.53	"
1871 to 1879, . .	.32	.18	.50	100 "

THE RICH HILL IRON ORES.

BY F. P. DEWEY, WASHINGTON, D. C.

RICH HILL is situated in the famous car-wheel iron region of Southwestern Virginia, and although it contains many iron ores, this paper will be devoted chiefly to its car-wheel ore.

Geologically, Rich Hill is somewhat difficult to describe, as the strata of the region are seriously folded and contorted. It lies at the base of one of the primordial spurs of the Blue Ridge, the ore appearing as a sedimentary deposit on the limestone No. 2, sometimes showing an imperfect stratification, but generally being an

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irregular formation consisting of ore in lumps of all sizes, together with some sand and gravel, and is supposed to be Trenton. It is comparatively long and narrow, its longitudinal outlines being determined by Big and Little Reed Island creeks and New River, the latter flowing along its northern base for a mile and a half. Its elevation is 335 feet between the creeks and river, and its area is 400 acres, of which at least 300 are ore-bearing. The ore has been very thoroughly tested by exploration shafts through its length for a mile and a third, and across its entire width. A careful calculation based upon this examination shows that it is a very low estimate to place the amount of ore at 2,000,000 tons. It is somewhat difficult to explore the ore by means of small shafts, as many of the large masses are considerably honeycombed in some localities; but no difficulty would be encountered in approaching it by large open cuts, which is the most convenient way to mine it. This difficulty of exploring has prevented the shafts being carried to a greater depth than 34 feet in the ore, but there is no reason for supposing that the ore does not extend to a much greater depth. The following average analyses show the quality of the ore to be most excellent:

Nos. 1 and 2 are representative lump ores from opposite ends of the ore lands. No. 1 is situated 150 feet up the hill, and has already been explored to a depth of 20 feet. No. 2 is 250 feet up the hill, and has been explored to a depth of 34 feet.

No. 3 is also a lump ore from very near the top of the hill intermediate between Nos. 1 and 2, from a surface opening for the supply of the forge.

No. 4 is an unwashed fine ore occurring with No. 2.

	1.	2.	3.	4.
Water,	12 51	12 91	15 83	13.94
Silica,	3 50	4.07	4.17	5.26
Alumina,	1.47	2.90	3 27	4.17
Sesquioxide of iron,	81.92	79.49	75.42	75.96
Oxide of manganese,	0.25	0.32	0.22	0.32
Lime,	0.17	0.14	0 13	0.17
Magnesia,	0.40	0.38	0.26	0.37
Phosphoric acid,	0.15	0.13	0.16	0.17
Sulphuric acid,	Trace.	Trace.	Trace.	Trace.
Total,	100.37	100.34	99.46	100.36
Metallic iron,	57.35	55.64	52.79	53.20
Phosphorus,	0.066	0.059	0 068	0.073

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The following are partial analyses of second samples of Nos. 1, 2, and 3:

	1.	2.	3.
Metallic iron,	54.87	57.68	54.60
Phosphorus,	0.083	0.081	0 050
Sulphur,	Trace.	Trace.	Trace.

The following ore is confined to a small area in the same locality as No. 3, and is in excellent favor at the forge on account of its physical condition, being known locally as "Black sand ore;" it is subjected to washing to prepare it for use:

Water,	11.63
Silica,	8.63
Alumina,	2 52
Sesquioxide of iron,	81.16
Oxide of manganese,	0 26
Lime,	0.43
Magnesia,	0.46
Phosphoric acid,	0.45
Sulphuric acid,	None.
Total,	100.54
Metallic iron,	56.82
Phosphorus,	0.195

In regard to the following ore little can be said, as it has never been explored and is not included in the general estimate of Rich Hill:

Water,	18.82
Silica,	6.34
Alumina,	2.96
Sesquioxide of iron,	74.06
Oxide of manganese,	1.35
Lime,	0.15
Magnesia,	0.42
Phosphoric acid,	0.46
Sulphuric acid,	None.
Total,	99 56
Metallic iron,	51.85
Phosphorus,	0.200

Topographically it would be very difficult to imagine a more suitable location for the manufacture of car-wheel metal. The ore being on both sides of a small hill is very accessible, free from all liability to trouble from water, and, in fact, free from all difficulty in mining. At the confluence of the two creeks is a location presenting many ad-

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vantages for a furnace; there is an abundance of water-power; the ore is within easy reach, and up the Big Creek there is an almost unlimited supply of charcoal.

At the present time the only use of the ore is for the supply of a small forge of three fires making 100 tons of most excellent bar iron per year. The great and only drawback to the rapid improvement of the region is the lack of transportation facilities; the nearest point on a railway is Martin's Station on the Norfolk and Western Railroad, which is fifteen miles from Rich Hill; but the completion of an ardently hoped for and expected branch railway in the near future will certainly make Rich Hill, with its many advantages, one of the most desirable positions for the manufacture of car-wheel iron.

NOTE ON BLACK BAND IRON ORE IN WEST VIRGINIA.

BY S. P. SHARPLES, S.B., BOSTON, MASS.

HAVING occasion a few weeks ago to investigate the subject of black band iron ore in West Virginia, I was surprised at being met at the outset with a denial of its existence. One gentleman went so far as to offer one hundred dollars an acre for any land in West Virginia that contained a seam or vein of even a single foot in thickness, and when shown the ore he acknowledged that it was genuine, but declared it had been imported. That black band does occur in West Virginia is to-day well known to a number of persons. There is a seam on the Gauley River of about a foot in thickness of good ore, which I understand Mr. Lewis and others are making preparations to work. The great trouble with black band ores as heretofore found in this country has been their limited extent. At Fort Washington, for instance, they had a very fine showing of ore, but it soon gave out.

It has also been asserted that the black band ores of the Western Coal Measures were worthless in the furnace, and Fort Washington has been pointed out as an example of the fate of any one who should undertake to work them. But they have been successfully worked at Youngstown and in other parts of Ohio, and I am assured by old furnace-men from Ohio that there is not the slightest difficulty in working them if properly managed.

The deposits to which I wish to call the attention of the Institute,

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are situated about nine miles from Charleston, West Virginia, and lie at the head waters of Davis Creek. This bed has not been fully explored yet, and has not been worked. Only one drift has been driven into it, and that only about sixty feet. But the bed has been found and identified over a tract of some 1500 acres.

This ore is compact, and resembles in appearance cannel shale. Various analyses have been made of it at different times since 1871, when it was first discovered, with about the following results:

For purposes of comparison, I give also an analysis of the Helen ore, Hocking Valley, Ohio, and a Welsh ore:

	Davis Creek.	Helen.	Llanelly.
Silica,	3.60	4.93	7.20
Phosphorus,	.25	.87	.295
Sulphur,	.41	1.07	.26
Metallic iron,	31.46	36.43	33.68
ROASTED ORE.			
Metallic iron,	64.	50.80	56.00

The ore loses rather more than half its weight in roasting.

The bed appears to hold its own over the area of which I have spoken, and to run from four to five feet thick.

The analysis of the black band ore on the Gauley River is almost identical with the above.

NOTES ON THE HARD-SPLINT COAL OF THE KANAWHA VALLEY.

BY STUART M. BUCK, COALBURG, WEST VIRGINIA.

THE term "splint" seems to have been adopted to describe the fracture of the hard bituminous coals of West Virginia. It is not a scientific name, but rather a trade term, and does not indicate a correspondence with English splint. At present it is a popular word, and is very loosely applied to coals of various qualities, in the desire to improve their sale. The Kanawha splint is distinguished by its hardness, dull lustre, coarse fibrous structure, its purity, and especially its resistance to atmospheric influence. It kindles very readily, burns with a bright flame, but does not cake, so that a lump when half consumed, may be broken by a slight blow in its plane of cleavage, though it will resist a strong blow in any other direction. I have seen pieces that have been exposed to frost and sun

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for a dozen years, that are now as firm, and ring as clearly when struck, as though freshly mined.

The principal splint vein worked on the line of the Chesapeake & Ohio Railway, is that known as the Coalburg seam. It has been regularly mined for the last seventeen years. The Kanawha & Ohio Coal Company began mining it on their property at Coalburg, in 1864, shipping by river till the opening of the railroad, in 1872.

The Coalburg vein worked at Coalburg, East Bank, and Paint Creek, is about 450 to 500 feet above the track of the Chesapeake and Ohio Railway, and about 150 feet below the Flint Ledge, which is a stratum of gray, blue, and black flint, running very regularly through the country, and constantly referred to as a base-line for the location of the different veins.

The section of the Coalburg vein is as follows, counting upwards from the slate floor:

A. Bottom bench, hard splint.

B. Middle bench, splint mixed with softer coal to some extent.

C. Bone or "niggerhead," sometimes split by a thin layer of coal.

D. Top bench of hard splint.

The whole thickness of the coal, including the bone, is 3′ 8″ to 4′ 6″, and counting the bone as belonging with the top bench, the three divisions are of nearly equal thickness.

The niggerhead is from six to eight inches thick, and as it does not separate freely, an additional loss of two inches of coal is frequently incurred. Constant watching is required to prevent the niggerhead from being loaded with the coal, as it is so similar in appearance to the coal, that in a dim light, or when coated with dirt, it is only to be distinguished by its greater weight.

The roof of the Coalburg vein is usually a heavy dark slate, varying much in character; sometimes so strong as to require little or no timber in a room of twenty-four to thirty feet wide, and again so bad that no posting will hold it in an eight-foot entry. At times the roof slate runs out and is replaced by the overlying sandstone, which is remarkably strong, so that usually no timbers are required in rooms of ordinary width, and after the pillars have been drawn, the roof has been known to stand for a long time, unsupported, over a space forty yards square. This character of the roof has its disadvantages, as it makes the drawing of pillars more dangerous. The sandrock will hold up for a long time, and then is liable to fall

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with little warning, and in such masses as to crush down all supports, and break even beyond the face of the coal.

The bottom slate, forming the floor of the vein, varies from half an inch to four feet and upwards, and is underlaid by a seam of soft bituminous coal, one foot to three feet thick. This soft coal is of little value for fuel, but if washed would make excellent coke. When the bottom slate, which divides the splint and the soft coal, does not exceed three inches in thickness, and there is any parting in the soft coal, the bearing-in or mining, is made below the slate, so as to avoid wasting the more valuable splint coal, and to gain additional height.

Theoretically and geologically, the coal seams of the Kanawha valley dip very regularly to the northwest at the rate of about fifty feet to the mile; but practically, the coal lies in basins, and the dip is so frequently reversed, that the question of drainage is often a very annoying problem. There is not sufficient dip to concentrate the water, and it is impossible to tell in advance what the dip will be. This adds to the difficulty of satisfactory and economical mining, owing to the danger of water whenever the roof is broken either by drawing pillars, or by long-wall work. The water finds its way through the swamps as they are called, and drowns out the workings at a distance.

The splint coal is prepared for market over an inch and a quarter screen, and the nut coal is cleaned over a half-inch screen. The miners are paid by weight for the screened coal, and the bushel of 80 pounds is the unit, for which, at present, the price of digging is 3½ cents, or 98 cents per ton of 2240 pounds. On the railroad the coal is sold by the long ton, but in the river markets it is sold by the bushel of 2688 cubic inches, measured in the barge. These barges carry from 8000 to 12,000 bushels, and are usually twenty-four by one hundred and thirty feet, with five to six feet draft.

Splint coal is especially adapted for use as domestic fuel in open grates, and is valued by shippers and dealers for its ability to resist breakage. It is a good gas coal, giving tests fully equal to the Penn and Westmoreland, but it cannot be mined to compete in price with the softer coals.

It is a favorite locomotive coal, giving results superior to the Youghiogheny, and it is an excellent coal for blast-furnace use. It can be used without coking, and its purity is vouched for by the fact, that in 1873–74 it was used in making so-called charcoal pig-

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iron, and when it did not exceed two-thirds of the fuel charge, the result was said to be good.

In the preparation of the splint, as well as the softer varieties of bituminous coal, the aim is to avoid breakage in every possible way, so that the coal may reach its market in attractive form. The operator grudges every foot of fall in the screening and loading of his coal on the railroad or at the river, but when coal is shipped by sea it is so roughly handled in loading and discharging vessels, that all previous efforts are rendered vain. There is great need of some decided improvement in this respect.

There are a few points on which I would like to invite some discussion:

1st. The probability of any relation between the topography of the country, and the character of the coal-seams 100 and 300 feet below the surface. The most experienced miners claim that a rich flat mountain top will be underlaid by a good and regular seam of coal, and on the contrary, that any sharp, rocky point or ridge is likely to indicate a horseback or fault below. They also look for a swamp, in every case, near the crop of the coal. I have not been able to trace any foundation for these claims, either in fact or theory.

2d. The relation between splint and cannel coal. The Coalburg seam, now being worked directly fronting the Kanawha River, is supposed to be the same vein as that opened five miles back, on Paint Creek; but in the latter place it has become thicker, and part of the splint is replaced by cannel. The total thickness is about ten feet, of which two to three feet are cannel; and the singular part is, that in one place the cannel occupies the centre of the vein, while at a few hundred feet distance, it appears near the bottom. Pieces of coal may also be found which show nothing but splint upon one side, while the other is banded with cannel.

3d. I have noticed a peculiar occurrence of coal in the sandrock roof of the vein. In one place, where a fall occurred, exposing a section of the sandstone, it showed a number of blocks of coal imbedded in the rock; not stringers or layers, but angular blocks of splint, as well defined as though they had been picked off from a coal car and placed in the sand while it was being deposited. I have also had two singular specimens brought to me from the slate immediately underlying the splint. One was a piece of milk quartz, and the other of flint, both rounded, and of about ten pounds weight.

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4th. Has it been determined under what circumstances the fibrous coal known as Dant or Mother Coal was deposited?

ON THE SOLUTION OF PIG IRON AND STEEL FOR THE DETERMINATION OF PHOSPHORUS.

BY N. H. MUHLENBERG AND THOMAS M. DROWN, EASTON, PA.

It is often a tedious matter to get a solution of pig iron or steel, for the determination of phosphorus, which is absolutely free from silica. Where pig iron rich in silicon is dissolved in hydrochloric or nitric acid in the usual procedure, it is necessary, not only to evaporate the solution to complete dryness, but to heat the dry residue for some hours in an air-bath to a temperature of about 120° C. The oxide of iron is thus rendered insoluble in nitric acid, and is only slowly dissolved by hydrochloric acid.

In the method of determining silicon by nitric and sulphuric acid, described in the *Transactions* of the Institute, Vol. VII, page 346, and Vol. VIII, page 508, we obtain in one or two hours a solution of the iron in the form of ferric sulphate entirely free from silica, and containing free sulphuric acid. It occurred to us that this solution might be made available for the determination of the phosphorus by the molybdate method.

The following experiments were tried with unsatisfactory results. 1st. The iron was precipitated by ammonia, the precipitate filtered, washed, and dissolved in nitric acid. 2d. The iron was precipitated as basic acetate and dissolved in nitric acid. 3d. The solution was neutralized by ammonia, and nitric acid added in small excess. In all these cases the phosphorus obtained by precipitating by ammonium molybdate and magnesia-mixture was too low.

The following method was then tried with success. The filtrate from the silica and graphite was evaporated to small bulk and heated in a porcelain dish on a sand-bath until fumes of sulphuric acid ceased to escape. The dry residue was taken up with dilute nitric acid and the solution precipitated by ammonium molybdate. The phosphorus was weighed as magnesium pyrophosphate. The results were satisfactory.

To save time, the original solution of the iron in nitric and sulphuric acids was evaporated to dryness and heated as before until

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sulphuric acid fumes ceased coming off. Nitric acid was then added until all the iron salts were dissolved, and the solution was filtered off from the silica and graphite. The filtrate was directly precipitated by molybdate solution. The results thus obtained were likewise satisfactory as regards phosphorus, but the silicon determination by this method was frequently too high, owing to imperfect solution of the iron after evaporation to complete dryness.

We have not tried the direct weighing of the yellow precipitate by this method, but see no reason why it should not be weighed by those who prefer it.

The following analytical results were obtained by N. H. Muhlenberg in the laboratory of Lafayette College on two samples of pig iron. The amount of borings taken was in all cases about one gram. These samples contained, respectively, 0.333 and 0.810 per cent. of phosphorus as determined by the following method: Solution in nitric acid, evaporation to dryness, heating in air-bath for several hours at a temperature of 120°, re-solution in hydrochloric acid, expulsion of the hydrochloric by nitric acid, precipitation in small bulk, made nearly neutral by ammonia, with ammonium molybdate, solution in ammonia, and precipitation with magnesia-mixture.

Sample No. 1.

By evaporation of the original solution to dryness.		By evaporation of filtrate from original solution to dryness.	
Silicon.	Phosphorus.	Silicon.	Phosphorus.
2.397	0.334	2.400	0.333
2.40	0.332	2.380	—
2.45	0.332	2.396	0 331
2.44	0.327	2.399	0.318
2.399	0.332	2.398	0.332
2.41	0.329	—	0.332
Average, 2.416	0.332	2.394	0.329

Sample No. 2.

1.052	0.781	0.895	0 796
1.043	0.822	0.801	0.839
0.875	0.832	0 867	0.805
0.899	0.810	0.844	0.798
0.844	0.798	0.847	0.791
0.843	0.800	0.848	0.774
0.828	0.802	0.854	0.771
—	0 813		
0.838	0.806		
0.839	0.820		
Average, 0.896	0.808	0.850	0.796

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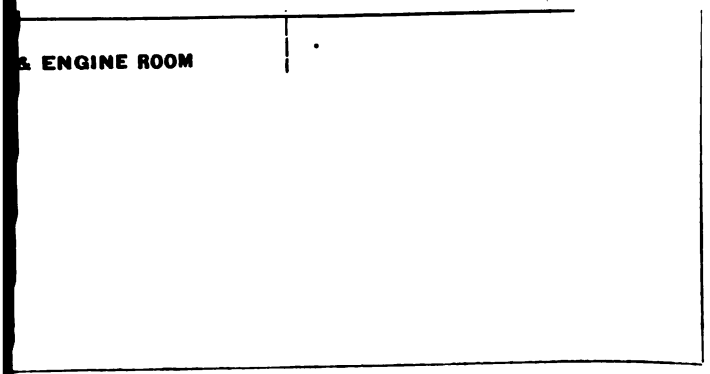

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NOTES ON GOLD-MILL CONSTRUCTION.

BY AUGUSTUS J. BOWIE, JR., SAN FRANCISCO, CALIFORNIA.

THE discovery of the auriferous cement gravel deposits in and near Deadwood Gulch, Lawrence County, Dakota Territory, in 1876, created a mining excitement, and rush to the Black Hills. Numerous ten and twenty-stamp mills were built on Deadwood Gulch; Central City and the town of Deadwood sprang into existence, and became the centres of the mining industry of the Hills.

Gold quartz deposits were subsequently discovered and located on a so-called mineral belt, extending from Whitewood Creek on the south, to Deadwood Gulch on the north. A northerly group of these quartz locations was purchased in December, 1877, by parties in San Francisco, who formed a company, incorporated under the name of the Father de Smet Consolidated Gold Mining Company. This company immediately commenced the work of exploration. The deposits were proved to be extensive, and easily mined, but it was found that the ore, on an average, would not yield more than $10.00 per ton* of 2000 pounds.

At this time the cost of supplies and materials in the Hills was high. Miners' wages were $3.50 per diem, and custom mills charged $6.00 per ton. The successful working of mines on "the belt" necessitated cheap milling. The ores being of so low grade,† this could be accomplished only with large and economically running mills.

To insure the greatest possible economy, the Father de Smet mill

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* Up to December 31st, 1879, the de Smet mine had produced bullion of the value of $718,211.63 from 76,155 tons of ore, being an average value of $9.41 per ton. During the year ending December 31st, 1879, the mine produced 46,344 tons, which yielded $425,360.42, or $9.18 per ton. The total gross cost of working for the corresponding period, including deadwork, exchange, legal expenses, etc., was $219,914.82. The yield of the mine for the year 1880 (*Engineering and Mining Journal*, February 5th, 1881), was $600,011, with total expenses of mining and milling, of $313,108.

† The first 4083 tons extracted from the de Smet mine, were selected, yielding $62,783.97. The next 25,728 tons produced $230,067.24. The total 29,811 tons were weighed, and worked at custom mills. The yield of the first 409 tons from the Golden Terra Mine was $11.44 per ton.

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(which was designed and constructed under the immediate supervision of the writer), was built on a plan different, in some respects, from any hitherto erected. The machinery, while of the most approved construction, did not vary essentially from that of other mills, but the arrangement of the building was novel, to a great extent, and has since proved so excellent, economically, that a detailed description of it may be of interest to many. The special objects in view in the arrangement were:

1st. The constant supervision of the batteries, tables, and sluices, and consequent safeguard against robbery.

2d. Free access to all parts of the machinery, and room for handling the same.

3d. Very large ore-bin capacity, to insure steady milling.

4th. The least possible manipulation of the material in all stages of reduction.

Among the results attained by this construction of the mill besides those hereafter mentioned, the following may be briefly noted here.

The building has been thoroughly tested, and at times there have been one and a half million pounds of ore in the bins without any resulting damage or straining of the structure. The rock breakers, which are fifty-three feet above the battery floor, have been run to their full capacity, with the whole mill in operation, without causing much, if any, vibration in the building, or even on the car track in the top of the main division.

An exceedingly limited number of employés in the mill is requisite, namely:

1 Head amalgamator.
3 Assistant amalgamators.
2 Feeder tenders.
1 Chief engineer and mechanic.
2 Assistant engineers.
1 Fireman.
5 Rock-breaker men.
1 Watchman.
1 Carpenter.
1 Blacksmith.

18 Total number of men required per diem to run the mill to full capacity.

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THE FATHER DE SMET GOLD MILL.

The ground for the Father de Smet eighty-stamp gold mill, was broken about the first week of June, 1878. The site selected was on the side hill, some 650 feet northeast of the Justice shaft of the de Smet mine, at a point 400 feet below the mouth of the shaft, and at an elevation of 30 feet above the bed of Deadwood Gulch.

A space 200 feet in length by 80 feet in width, was excavated, trenches and pits for batteries and machinery duly prepared, and the building erected on the solid slate country-rock. The material from the excavation was dumped over the hillside, so as to form, in front of the mill, a large area, which was subsequently used for a wood-yard, and for other purposes.

By reference to the accompanying drawings (Plates I. and II.), the following description of the construction and arrangement of the mill may be readily understood.

The Building.—The entire structure, which faces the north, covers a space 140 feet long and 60 feet wide. The elevation of the main building from the mud-sills to the apex of the roof is 75 feet. Its greatest length is east and west. It was constructed with three distinct compartments, which for purposes of description, will be designated as the east division, main building, and west division. The sides of the structure are boarded and battened, and the roof is shingled. The whole is painted on the outside with two coats of metallic fire-proof paint, and the interiors of the west and centre divisions are whitewashed. The east and west divisions are finished to correspond with the main building.

The east division is 52 feet long and 60 feet wide, and contains the engine, boiler, machine and lathe rooms. The machine-shop is well supplied with all the necessary implements for mill work. The lathe is 30″ x 23′, and fitted with a full complement of tools.

The main or centre division, 68′ x 60′, contains the batteries, rock breakers, and ore-bins.

The west division, 20′ x 60′, is used for the clean-up room and repair shop. It contains a small cast-iron clean-up pan, tubs for panning out amalgam, tailings, etc.

The accompanying plans show that the construction of the end divisions is quite simple, and a description of the same will, therefore, be omitted.

The building is provided with numerous double and single

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windows. The portion of the battery floor adjoining the engine department is, during the winter days, not as well lighted as desired. This might be easily remedied by substituting glass for the boards in the sides of the engine-room. A change in the style of battery bracing would improve the light over the tables, and permit the use of electric illumination during the night.

Materials.—The timber used in the construction of the building was the best available pine found in the hills. The mud-sills were hewn timbers, and the posts, beams, caps, and rafters, were of sawed lumber. The timber for the cross-beams came in lengths of 30 feet, which were extended by fishing and scarfing as required.

The shingles, laid 4″ to the weather, were such as could be obtained, heart shingles being, of course, desired. All the mortises and tenons were carefully cut and accurately fitted.

The Main Floor.—The main building is erected on eight lines of mud-sills, each line being 71 feet long. The sill timbers are of different lengths, 18″ x 24″ in width and thickness. Those on the outer lines of mud-sills are securely lock-spliced together. The cross sills are 12″ x 21″ and 62′ long, bolted to the mud-sills with 1″ iron bolts, ninety-six bolts in all being used for this purpose. The sills are laid on the solid bed rock, and grouted with lime. Due precaution was taken to insure a perfect foundation, all weak places being dug out and filled in with masonry.

The ground or battery floor is double planked, carefully laid with a pitch from the batteries to the centre line of the building, along which line, under the floor, run two sluices, one for each half of the mill, receiving the tailings as discharged from the plates. These two sluices incline towards one another, meet in the centre of the building, and discharge their contents into a quicksilver trap placed at their junction. This trap discharges into a sluice, which runs at right angles to the sluices already mentioned, and in turn discharges into a second quicksilver trap, after passing which, the tailings flow into the gulch.

The main structure is erected on the outer mud-sills. The lower frame of the building is formed with twenty-four side posts of sawed timber, each 12″ x 20″ and 23′ long. Each post is mortised in the sills with a 4″ mortise, 10″ deep, and double draw-pinned. There are standing braces, with 6½ feet to 8 feet run of 10″ x 12″ timber to every post. The posts on each line of sills correspond with one another. They are set at irregular intervals of from 4′ 10″ to 7′ to suit the construction and arrangement of the machinery.

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The several spaces between the posts, commencing on the east end (the numbers designating at once both sides), are as follows:

Posts 1, 2, and 3. Space between each 4′ 10″.

Posts 3 and 4. Space 5 feet.

Posts 4, 5, and 6. Spaces 4′ 10″ each.

Posts 6 and 7. Space 7 feet.

Posts 7, 8, and 9. Spaces 4′ 10″ each.

Posts 9 and 10. Space 5 feet.

Posts 10, 11, and 12. Spaces 4′ 10″ each.

The side posts are capped with two sills (one on each side), 18″ x 18″ x 66′ 8″. These sills are held to the posts with double mortises and tenons (3″ x 12″) double draw-pinned from both sides.

Twelve cross-beams, 12″ x 18″ and 62′ in length each, rest on these upper sills to which they are bolted with 1″ iron drift bolts.

Hanging braces, 12″ x 12″ with an 8-foot run, connect the cross-beams with the lower side posts, and stress-bolts of 1¼″ iron, with bevel washers on each end, run parallel with the braces.

The Ore-shoot Story.—Upon the cross-beams just described, immediately over the lower posts, stand twenty-four upper side posts, 12″ x 16″ x 24′, each. These posts are mortised into the lower cross-beams with a 4″ mortise, and double draw-pinned, similarly to those in the lower side posts.

Twelve tie beams, 12″ x 18″ x 62′ cap the upper posts with which they are connected by means of mortise and tenon joints. Size of mortise, 4″ wide, 16″ long, 10″ deep. The centres of the tie-beams are supported by twenty-four shoot braces, 12″ x 12″ x 34′ each, the lower ends of the braces being mortised and bolted with ¾-inch iron bolts into the cross-beams, at a point 6′ in from the side of the building.

Twenty-four strut braces, 12″ x 12″ x 16′, connect the centres of the shoot braces on the lower sides with the centres of the cross-beams.

The tie-beams and cross-beams are connected at their centres with king bolts, 1½″ iron, 26′ long, thus making twelve perfect braces, each forming a truss, and supporting the upper story of the building. The trusses were built slightly crowning.

The twenty-four shoot braces are in turn strengthened by twelve sets of 6″ x 6″ girts, upon which is securely spiked a double thickness of 2″ plank with broken joints. This forms a substantial brace longitudinally for the entire structure, and also serves as the floor of an ore-shoot to the bins. Twenty-four horizontal bolts, 1¼″ diameter,

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bind the upper posts to the shoot braces at the centres, as shown in the plan.

There are twenty-four (12″ x 12″) short posts supporting the lower ends of the ore-bins, and resting on the cross-beams. These posts are mortised at their upper and lower ends.

The ore-bins are separate compartments, 4′ x 4′ 10″ x 8′, constructed with a double thickness of 2″ plank, and lined on the bottom with iron. They are supported below by beams 12″ x 14″ in size, which at one end are mortised, tenoned, and double draw-pinned to the lower side posts, and hung at the other end from the cross-beams by rods 1¼″ diameter by 12½′ long.

What have been described above as ore-shoots form in fact the upper parts of the ore-bins. For every battery of five stamps the bins have a funnel-shaped mouth and a door arranged for regulating the discharge to the feeder.

The roof of the building, pitched at an angle of 42°, is of the ordinary queen truss plan. The rafters are 2″ x 10″ x 42′, and rest on plates 8″ x 12″, which lie on the tie-beams immediately over the upper side posts. Ventilators are provided on the top of the building.

Engine, Boilers, and Shafting.—The machinery of the mill was constructed at the Union Iron Works, San Francisco, California. The engine was made sufficiently large to drive the present eighty stamps, and twenty additional, should the latter be required.* It is a horizontal engine, fitted with Meyers's cut-off, known as size No. 5. The cylinder is 20″ diameter with 42″ stroke. The engine occupies a space of 5′ x 21′ 6″. The height from base to centre is 24″. The shaft is 9″ in diameter. The whole weight of the engine is 25,000 pounds. The balance-wheel is 18′ in diameter, cast in eight segments,† and weighs 19,000 pounds.

There are two boilers 54″ in diameter, 16′ long. The shells are $\frac{5}{16}$″ and the heads $\frac{7}{16}$″ thick. Each boiler contains forty-six tubes 3½″ in diameter, spaced 4½″ in vertical rows. The tubes are securely fitted in the boiler with an expanding mandril, and their ends beaded over. There are two manholes; at one end above, and at the other

* The lumber for this addition was purchased in 1879. Two more boilers will be required if the twenty stamps are added. This change will necessitate detaching the west division from the main structure, and shifting it about twenty feet further west.

† Weight of eight segments 14,360 pounds. Fly-wheel, centre, and follower, 1320 pounds.

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below, the tubes. To the top of the boiler is riveted a 6″ diameter chock with a 54″ circle, and to this is bolted a 6″ safety valve, fitted with brass valves, complete with lever and ball. A 6″ flange is also bolted to the same for the steam-pipe. Each boiler is provided with a water-gauge fitted to its front with circulating pipes, and three gauge cocks tapped in the front end. There is a steam gauge 8″ face with siphon and cocks, and one 6″ steam whistle with 2″ cocks.

The steam drum, 40″ in diameter and 12′ long, is connected with the boilers by two chocks 8″ diameter, 40″ circle. The drum is provided with a manhole on one end. A mud drum, 24″ in diameter and 14′ long shell (A. C. iron), ¼″ thick, heads $\frac{5}{16}$″, provided with a manhole on left end, is connected with the rear end of boilers by two chocks 8″ diameter and 24″ circles. On the underside of the mud drum there is bolted a 4″ diameter blow-off elbow with a 4″ diameter mud valve attached.

The best No. 1 A. C. brand iron was used in the boilers, steam, and mud drum, and the iron rolled to show the brand on the outside. The horizontal seams of the shells were double riveted, and the rivets spaced to government standard and driven by hand. The edges of plates for the boiler, steam, and mud drums were bevelled on a planer before being rolled, and caulked inside and outside.

There is a double fire front of cast iron 1″ thick, 12′ long, 6′ 6″ high, with a moulding around the edges. It is spaced to leave 4″ between the boilers, and made with carrying brackets to hold the boilers, and cover the heads of the rivets, leaving the boiler heads flush with the fronts. It is fitted with fire and ash-pit doors. The front plate consists of three pieces of wrought iron, one ½″ x 6″ x 12′, and the other two ¾″ x 2½″ x 6′ to suit the fronts. The boilers, supported by two boiler stands, 18″ base, and 18″ high, one back bearer 1″ x 6″ x 11′, two wrought-iron hollow arches, and one arch brace 1″ x 8″ x 10′, are inclosed in double walls of brick, so constructed as to form an air-chamber. The whole is held in place with six anchor rods, 1″ x 19′ 6″, with a nut on each end, eight tie-rods, 1″ x 14′ 6″, with nut and washer on each end, and eight wall-braces 8½′ from centre to centre of holes. The grate surface is 12′ wide, length of bars 4′ 6″ each. The front of the boilers is covered with a double breeching, made of the best Thornycraft iron, No. 10 *g.*, and to this was fitted a smoke stack, 42″ in diameter, 60′ high, made of Nos. 10 and 12 Thornycraft iron, fitted with end and guy rod bands of ½″ x 12″ iron. The guy band is fitted with four eye-bolts ⅝″ in diameter. There is an iron

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tubular heater, 24″ in diameter, and 8′ 7″ long, front face to face of flanges. The shell is of $\frac{3}{16}$″ iron, fitted with cast-iron heads 3½″ deep, and covers bolted to the same. The holes are tapped in each end for 2″ gas pipe. The heater contains 24 tubes 2½″ in diameter, and 8′ long. Two chocks, 8″ diameter, with 16″ flanges, are riveted to the heater 15″ from each end, at right angles from each other. A flange 16″ diameter, for an 8″ galvanized iron pipe, is bolted to the outlet chock. A 1″ drain cock is fitted to the bottom side of the heater, opposite and under the outlet chock.

To supply the boilers, and for other purposes, there is a No. 5 Knowles steam pump. The engine is placed on a stone foundation set in hydraulic cement, the bed rock being excavated for this purpose. The anchor bolts are 11′ long.

The main shaft and driving pulleys are situated in the centre of the east end of the main building. These pulleys (96″ diameter), by means of six-ply rubber belts, drive 54″ pulleys on the countershafting; and eight other pulleys (also 54″ in diameter) on this line shafting are belted to 72″ pulleys on the cam-shafts. The cam-shaft belts are provided with tightener pulleys 15″ x 16″ in size. There are two lines of line shafting, one on each side of the main building, placed behind the batteries, and directly on the battery sills, the head ends being supported on pillow blocks. The machinery and line shafting are so placed as to be readily accessible.

The Batteries.—The batteries, sixteen in number, with five stamps each, are arranged in two lines, eight batteries on each side of the mill. They discharge to the centre of the main building. They are of the usual style, built independent of the building, and braced, one line against the other, with 12″ x 18″ timber, as shown in the plan.

The battery blocks are of selected two-inch planks, spiked together, broken jointed, standing on their ends, clamped longitudinally and bolted. It was difficult to obtain sound timber of sufficient size to make the blocks in the ordinary way, and recourse was had to the style of block above described.

Experience has demonstrated that this style of block is excellent, if not the best. Sound planks can be selected and put together, thus insuring a perfect material upon which to rest the mortars, a result not always secured when large timbers are used.

The blocks are placed in pits 12 feet deep sunk in the slate. The bottoms of the pits are levelled with a few inches of quartz sand, and the blocks are placed in position and securely clamped; quartz

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tailings are then run in, filling up the remaining spaces between the blocks and the slate. Each stamp weighs 758 pounds, and consists of:

1 stem, 13′ long by 3½″ in diameter, weighing 320 pounds.
1 tappet, diameter of face, 9½″; depth, 10″; weight, 100 pounds.
1 boss head, " " 8½″ " 16″; " 214 "
1 shoe, " " 8½″ " 9″; " 124 "
The die is 8½″ in diameter and 5½″ deep; weight, 89 pounds.

The tappets are set to drop the stamps from 7″ to 9½″, eighty-five drops per minute being the calculated speed. The cam shafts are 5″ in diameter in lengths of 14′ 6″ each, weighing 860 pounds.

Mortars, Shoes, and Dies.—The mortars are of the gold-mill pattern, with lining for sides and ends. The frame and lining of each mortar weigh about 4900 pounds. The accompanying drawing shows their construction in detail. They are set on the blocks and bolted to them, the tops of the blocks being previously covered with blankets. The groove shown in the centre of the bottom of the mortar was made for the purpose of holding the die to its place, each die being cast with a corresponding lug. As the dies wore down, it was intended to introduce a false bottom, or heavy casting, 3″ thick, fitting the bottom of the mortar, and provided with a lug for the groove in the mortar, and a groove in the top for the lug on the die. The object in view was to economize iron by wearing the dies as thin as possible without lowering too much the level of their surface. The screens used are No. 6, punched; size, 14″ x 52″. Experience has since shown that, with the frequent introduction of dies, the sides of the grooves chip, and the dies then require wedging. It has been further demonstrated at the mill that, when old dies were worked down on the false bottoms, the batteries by no means crushed as much rock as with new shoes and dies, though the line of discharge was kept relatively the same. This is accounted for by the irregular wear and tear of the shoes and dies, and the loss of weight. A very important question in milling low grade gold quartz is here presented, where economy requires that the largest possible quantity should be treated at the smallest possible cost in the shortest time, with due reference to the percentage of yield.

The conclusions so far arrived at are:

1st. That the square bottom is the best form of die.

2d. That there is no economy in using dies after their surfaces have been irregularly worn to any great extent.

In milling gold quartz almost the principal expense is the con-

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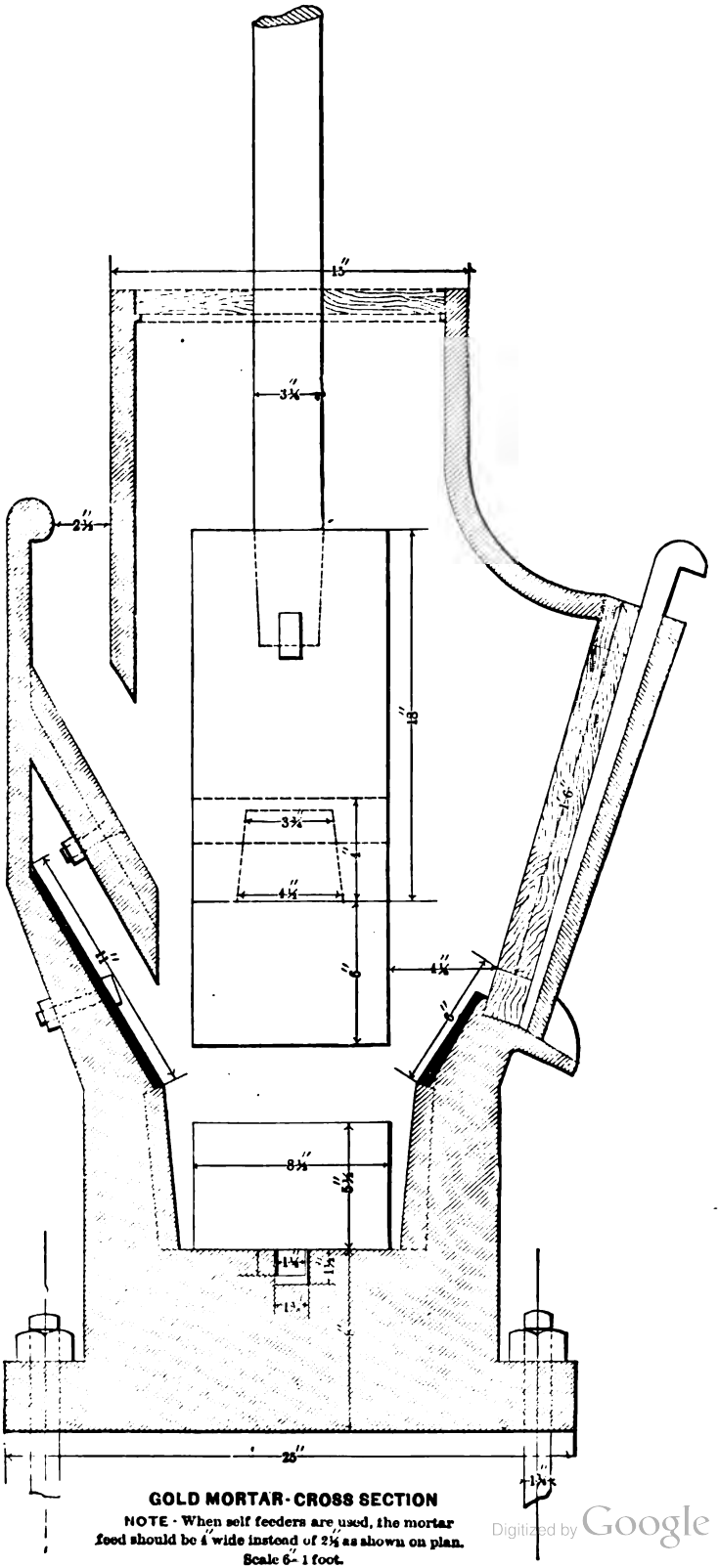

GOLD MORTAR - CROSS SECTION

NOTE - When self feeders are used, the mortar feed should be 4" wide instead of 2½" as shown on plan.

Scale 6" - 1 foot.

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sumption of shoes and dies, and any method by which a saving can be effected here is most desirable. If the above conclusions are correct, it is economy to cast shoes and dies with the smallest depth practicable. This necessitates at least monthly replacing, but it insures the largest amount of work per stamp with the smallest consumption of iron. In addition, it is estimated that the quantity crushed with new shoes and dies is so much in excess of that with those which are much worn as to well repay frequent renewal.

Feeders, Tables and Traps.—Immediately over the shafting on each side of the mill is the feeder floor. This floor is spacious and well lighted. There are sixteen of Hendy's patent self-feeders, eight on each side. They stand immediately back of the batteries, the lip of the feeder being on a line with the mortar feed, and the mouth of the hopper of the feeder being directly under the ore-bin discharge. The batteries, sixteen in number with five stamps each, are arranged in two lines, eight batteries on each side of the mill.

In front of each battery there is an inclined table covered with amalgamated soft copper plates. The tables are so located that they are all visible from any point on the main floor of the mill, and are thus constantly under the supervision of the amalgamators. At the lower end of each table there is a Eureka rubber,* which receives the tailings and in turn discharges them into a quicksilver trap. From the trap, the tailings pass over a small amalgamated copper plate placed below the floor and thence run into the sluice, previously described, situated in the centre of the mill. The traps are narrow wooden boxes with a centre partition which extends to within a few inches of the bottom. The boxes are lined with movable amalgamated copper plates. Above the main sluice, on a level with the floor, there is a track, on which runs a small car, used to transport material as may be required.

Rock-breakers and Grizzlies.—The rock-breakers, two in number, Blake's patent, 15″ x 9″ in size, placed immediately over the centre

* These rubbers were taken out subsequently and replaced by amalgamated soft copper plates. The cost of running the rubbers and the small amount saved by them did not justify their use. Moreover, the quantity of material crushed per battery was too much for the single rubber to work. The results were that the rubbers became virtually useless and the grinding entailed a loss in quicksilver. In the accompanying drawings the "cross-section through the main building," shows the mill with the Eureka rubbers as originally erected.

From August, 1879, to April, 1880, inclusive (nine months), in working 48,422 tons of ore, there was a loss of 928 pounds of quicksilver, or very nearly $\frac{3}{10}$ of an ounce of quicksilver to the ton of ore worked. This was after the rubbers had been taken out.

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of the apex of the shoot, are set on timbers laid longitudinally with the building on top of the upper tie beams, to which they are bolted with 1″ bolts. They are driven with 10″ belts from pulleys on the counter shaft, which is run with a 16″ belt from a 66″ pulley on the south line shaft. The mouth of each breaker is set on a level with a raised floor (on the upper tie beam), which is covered with wrought-iron plates, upon which the ore descends from the grizzlies.

The monthly capacity* of the mill was originally from 4400 to 5400 tons of quartz. Two additional rock-breakers have since been added, and the capacity of the mill has been increased to 6200 tons of quartz, and to a much greater amount (7500 tons) when the auriferous slate also is milled, which is now being done.

It has been conclusively proved in the Black Hills that in milling low-grade quartz, there is great economy in large rock-breaker capacity. The breakers should be set to crush fine. Each rock-breaker is supplied with ore fed over two grizzlies (one on each side of the breaker). The grizzlies, 4½′ wide by 12′ long, are set on an incline of 42°, and extend from the rock-breaker floor to the car-way which runs along the top of the mill. Each grizzly is composed of twenty-four bars of iron, 1″ x 2″ x 12′ set with spaces of 1½″ between the bars. The total weight of the four grizzlies is 8160 pounds.

The car-way in the main building connects with a tramway, which passes over the top of the west division, as may be seen in the plan, and extends to a self-acting elevator placed at the mouth of the lower tunnel of the mine.

Water Supply.—Water for the batteries is supplied from a 20,000 gallon tank inclosed in a room built against the south side of the main building. In the tank is a large sheet-iron drum, through which the exhaust steam from the engine is passed to heat the water. The temperature in the Hills during the winter ranges from 0° to —35° F. From this tank, 2½″ pipes distribute the water throughout the mill. Between every set of two batteries, for use on the tables, is attached to the water pipe a 1″ hose with nozzle. The boilers are supplied from a 15,000 gallon tank placed behind the engine-room.

Immediately above the mill, on the hillside, there is a tank containing 48,000 gallons of water for use in case of fire. As a protection against fire a 2½″ hose is always kept attached to a fire-plug in the boiler-room. On the rock-breaker floor, there is a fire-plug with hose attached. Water is delivered at this point by a direct

* The ore is estimated per car-load.

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connection with the 6″ main of the Central City Water Company. There are two fire plugs outside of the building supplied from the same source under a steady pressure of 100 feet, which, in case of need, could be increased to 400 feet. In front of the mill are the mill blacksmith-shop, assay office, retort and smelting rooms, all of which places are fitted with every necessary appointment for their respective work.

Cost of Construction.—The cost of the construction of the mill was as follows:

Mill lumber,	$13,706 61		
Shingles,	878 00		
Masonry,	636 75		
Cement,	82 50		
Hauling,	705 00		
Planing Mill,	850 00		
Lime,	207 70		
Miscellaneous,	367 00		
		$16,933 56	
Whitewashing,	359 15		
Copper,	1109 15		
Quicksilver,	414 10		
Belting,	952 47		
Fire-arms,	68 80		
Telegraph,	44 60		
Toll Gate Company,	74 55		
		$3,022 82	
Hardware,	5,603 27		
Nails,	886 33		
Machinery, including lathe,	35,566 73		
Freight,	24,075 42		
		66,131 75	
Total,		$86,087 63	
Deduct supplies on hand,		13,060 07	
Actual cost of all material and machinery,			$73,027 56
Contract on construction,	15,000 00		
Labor on pits, tank (48,000 gal.), mill, etc.,	4,652 44		
			19,652 44
Total cost of mill construction and material,			$92,680 00
TRAMWAY.			
Lumber and shingles,	1,528 00		
Labor,	1,333 00		
Survey,	87 00		
Sundries,	188 00		
Total,			3,136 00
GRADING MILL SITE.			
Labor, material, tools, etc.,			4,939 48
Grand total.			$100,755 48

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A VOLUMETRIC ESTIMATION OF MANGANESE IN PIG-IRON AND STEEL.

BY FREDERICK H. WILLIAMS, ST. LOUIS, MISSOURI.

THE object of this paper is to bring to the attention of those members of the Institute who are interested in the subject, a method for the estimation of manganese, which has been frequently used in the laboratory of the Vulcan Steel Works during the last eight months, and which is deemed worthy of more general use. It is simply an adaptation of well-known processes, for the purpose of determining this element in pig iron and steel.

In general, the method consists in precipitating the manganese as binoxide, dissolving in dilute sulphuric acid in the presence of an excess of a standardized solution of oxalic acid, and titrating the remainder of the oxalic acid left unoxidized with permanganate of potash.

For this method, therefore, two standardized solutions are needed, viz., a permanganate solution and an oxalic acid solution.

The permanganate solution is made so that 1 c.c. is equivalent to 1 mgr. of iron. By using so weak a solution and keeping the bulk of the solution to be titrated down to 75 c.c. or a little less, the accuracy of the process is greatly increased, since the final reaction is almost if not quite as sharp as if a stronger solution were used.

The oxalic acid may be of almost any strength, but if made so that 1 c.c. requires 3 c.c. of the permanganate to oxidize it, it will answer well.

The process is then, as follows: from 1 to 2 grams of pig iron or steel are dissolved in 40 to 50 c.c. of concentrated nitric acid with the aid of heat. As soon as solution is effected, in the case of steel, add gradually and cautiously, the solution being kept boiling, sufficient pulverized chlorate of potash to precipitate the manganese as binoxide. Two grams will be a great abundance. In the case of pig iron, first remove the carbon and silica by filtering the solution through asbestos and washing with concentrated nitric acid. Filter the strong acid solution in which the binoxide has been precipitated, through asbestos with the aid of the filter pump. When it has entirely passed through wash well with water. Blow the contents of the funnel into the beaker in which the precipitation was made and rinse the funnel with a little water.

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Put into the beaker an accurately measured quantity of the standard oxalic acid, a moderate excess over what the binoxide is capable of oxidizing, add water to bring the bulk of liquid up to 50 to 75 c.c., then 3 or 4 c.c. of concentrated sulphuric acid, and heat to 70° or 80° C. for a few minutes. The solution of the binoxide is speedily effected with the aid of a little stirring. Finally titrate the hot solution with permanganate. The presence of asbestos does not obscure the final reaction.

Suppose we have taken 1 gram of steel in which we suspect about one per cent. of manganese. Having separated the binoxide, we add, say 15 c.c. of oxalic acid of the strength already mentioned, and effect the solution as described. This 15 c.c. by itself would require 45 c.c. of the permanganate, but on titrating we use, say 25 c.c., the difference, 20 c.c., is equivalent to 0.020 grams of iron. Since 1 equivalent of binoxide of manganese converts 2 equivalents of a proto-salt of iron to the state of a per-salt, as shown by the formula

$$2\,FeSO_4 + MnO_2 + 2H_2SO_4 = Fe_2(SO_4)_3 + MnSO_4 + 2H_2O,$$

the solving of the simple proportion, $112 : 55 = 0.020 : x$ gives the weight of manganese equivalent to the 0.020 gram of iron. The value of x is 0.00982, and the per cent. is 0.982.

The results by this method agree very closely with those obtained when the manganese is determined as pyrophosphate.* Duplicates also, by their constant agreement, show the method to be reliable. In the last analysis on our records, the two results from the same sample were 1.112 per cent. and 1.108 per cent.

In analyzing spiegeleisen, less than 1 gram may be taken. A determination can be made in two hours.

MANGANESE DETERMINATIONS IN STEEL.

BY WILLIAM KENT, M.E., PITTSBURGH, PA.

DURING the discussions at the Philadelphia meeting in February last,† several speakers expressed their doubts of the general accuracy of chemical analyses of steel made by "iron-works chemists," and especially of determinations of manganese. Since the meeting, the discussion of the "practical value of chemical analyses" has been continued at some length in the columns of the *Iron Age*.

* Compare paper by S. A. Ford, *Transactions*, vol. ix, p. 397.

† *Transactions*, vol. ix, p. 529.

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In a letter to that paper I gave the results of ten determinations of the manganese in one cast of steel, showing wide divergence, and offered to give samples of the same steel for analysis to any chemist who should request it. Eight chemists wrote asking for samples, and from five of them I have received results, which I shall give below, together with the figures previously obtained, and a few brief notes on the methods used.

At the time the first analysis of this cast of steel was made, I was attempting to investigate the influence of carbon and manganese upon the strength and ductility of certain low-phosphorus open-hearth steels, and had almost arrived at the conclusion that manganese had no traceable effect upon these properties. Steels of about the same strength and ductility, made in a uniform manner of low-phosphorus stock, were found to be nearly uniform in carbon and silicon, but to vary widely in manganese. For instance, two plates, from different heats, were found to be nearly identical in physical properties and in chemical composition, except in manganese, which was reported by a chemist of large experience, and in whom I had every confidence (A. in table below), to be 0.434 and 0.98 respectively in the two plates. An accident led to these two plates being analyzed by a customer to whom they were sent as samples, and he reported them to contain 0.324 and 0.320 Mn (C.). Meanwhile a second analysis was made by the first chemist of the heat in which he had found 0.434, and the customer 0.324 Mn, and he reported 1.14 Mn. Two analyses, made some days apart, by a third chemist (B.), of a piece of the same plate in which 0.324 Mn had been found, gave the figures 0.613 and 0.58 Mn.

Here, certainly, was food for reflection, and I at once made up my mind to find out, if possible, how much manganese that plate of steel really contained. My own time being occupied with other matters, I was able to make only a single determination myself, using the acetate of soda process with precautions, as described by Mr. A. A. Blair, in the reports of the United States Testing Board. The result was 0.303 Mn, a figure in which I had but little confidence, as no opportunity was afforded for duplication.

A small piece of the same plate, about six by two inches, one-quarter of an inch thick, was then drilled over its whole surface, and a bottle filled with the drillings. This bottle was then used in furnishing other chemists with samples, care being taken to give each about an equal proportion of coarse and fine drillings, so as to avoid if possible the suspicion that the steel was not properly sam-

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pled. I will now give the complete list of results, the names of the chemists being suppressed, as I have no authority to publish them:

No.	Chemist.	Manganese found.	Process.
1.	A.	.434	Acetate soda and bromine.
2.	A.	1.14	" " "
3.	A.	.61	" " "
4.	B.	.613	" " "
5.	B.	.58	" " "
6.	B.	.83	Nitric acid and chlorate of potash.
7.	C.	.324	Not reported.
8.	D.	.451	" "
9.	D.	.453	" "
10.	E.	.308	Acetate, with modifications.
11.	F.	.391	Acetate process.
12.	F.	.885	Nitric acid and chlorate of potash.
13.	G.	.406	Acetate, with modifications.
14.	G.	.408	
15.	H.	.351	Acetate ammonia and bromine.
16.	H.	.380	
17.	I.	.562	Acetate soda and bromine.
18.	I.	.619	
19.	J.	.439	Acetate soda and bromine.
20.	J.	.374	
21.	J.	.313	Results 19 and 20 redissolved and determined by nitric acid and chlorate of potash.
22.	J.	.333	
23.	J.	.356	Nitric acid and chlorate of potash direct.
24.	J.	.333	
25.	K.	.438	Acetate soda and bromine; weighed as pyrophosphate.
26.	K.	.430	
27.	K.	.352	Nitric acid and chlorate of potash.
28.	K.	.364	
29.	L.	.38	Acetate, with precautions; weighed as pyrophosphate.
30.	L.	.39	
31.	L.	.38	
32.	L.	.32	Nitric acid and chlorate of potash.
33.*	L.	.33	

The brackets indicate duplicate determinations.

All of the results, except No. 1, are known to have been obtained from the same plate. No. 1 was from the same cast, but whether or not from the same plate is uncertain. Nos. 3, 6, 8, 9, and 13 to 18 inclusive, were from the bottle of drillings above spoken of. Nos. 11 and 12 were from a small piece of the original plate, the chemist preferring to make his own drillings. Nos. 19 to 24, inclusive, were from another bottle of drillings, the first having been ex-

* Analyses 25 to 33 have been received since the paper was read at the Virginia meeting.

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hausted. This second bottle of drillings was purposely made very fine, a fluted reamer being used, and the whole thickness of the plate being cut away so as to secure as great accuracy as possible in sampling, in case there should be a difference in manganese, at different distances from the surface, as is reported to have been found recently in England.*

I will now give a few notes concerning the chemists and their methods:

A. is a chemist, well up in years, of large and varied experience, and considered by a large clientage as a first-class authority. He still uses the acetate and bromine process, and considers it the best; but I fear he is laboring under a mistake, as I am informed he does not use the precautions thought indispensable by many other chemists, to free his precipitate from alkalies and oxide of iron.

B. is a young man of limited experience. He did use the acetate and bromine process until the Philadelphia meeting, but has now adopted the nitric acid and chlorate of potash method, as described in Mr. Ford's paper.† His result, No. 6, indicates that one or the other method, in his hands, is far from being accurate.

C. is a steel-works' chemist. I know nothing further concerning him. He was employed by the customer referred to above.

D. is a professor of chemistry. He reported that the determinations were made by his assistant, in whom he had every confidence. The agreement of duplicate analyses to within .002 of one per cent. is noticeable, especially as the figures are higher than those given by the majority of other chemists. To my mind they indicate a great uniformity of manipulation, with the possibility of an inaccuracy in method, tending with such manipulation to a constant plus error.

E. is only an amateur chemist, without sufficient experience to be confident of his own results.

F. I know only through correspondence. His results, by two entirely different methods, show remarkable uniformity, when compared with the great divergence in results obtained by these methods in the hands of other chemists. They would indicate that he has got rid of the common sources of error in the acetate and bromine process, and lead to a strong opinion in favor of his accuracy in manipulation. He writes as follows, concerning his method:

"The precipitate of phosphate of ammonia and manganese was in both cases redissolved in hydrochloric acid; a very little more phos-

* Engineering, April 15th, 1881, page 378.

† *Transactions*, vol. ix, p. 397.

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phate of soda added and reprecipitated with ammonia, then boiled until it assumed the crystalline form."

G. describes himself to me as a chemist from Dr. Drown's laboratory. His results also agree to within .002 of one per cent., but are .045 lower than those reported by D., and in my own opinion ("subject to revision") so much more accurate. He writes: "I use the basic acetate process, . . . wash the precipitate once on the filter, redissolve in as little HCl as possible, repeat precipitation, wash thoroughly, unite filtrates, and evaporate to 300 c.c. Filter, dissolve in HCl the small amount of iron which has separated during evaporation, and make a basic acetate separation in as small bulk as possible. Unite the filtrates and precipitate with bromine, dissolve precipitate in HCl, weigh as pyrophosphate, following Fresenius's instructions."

H. I knew six years ago as then a chemist of considerable experience. He writes: "The method used was the acetate of ammonia process, separation of MnO_2 by Br and weighing as Mn_3O_4. This probably gives results a trifle low, but I consider it still the best and most accurate process. The determinations resulted as follows: No. 1, 0.351 Mn; No. 2, 0.380 Mn. This you may say is not very satisfactory, but I detest manganese determinations in steel, and hope some day some chemist will discover a process more satisfactory."

I. writes me that he has had five years' general training under some of the best professors of this country, and three years' special experience in iron and steel laboratories. "During the latter period," he says, "I have had many a wrestle with manganese, and have come to the conclusion that with proper care, and notwithstanding the time required, the bromine and acetate method is by far the best that we have where anything like accuracy is required." His method he describes as follows:

"A slight permanent precipitate is formed in the solution by Na_2CO_3, then 4 c.c. of $C_2H_4O_2$ of 1.04 specific gravity added for each 500 c.c. of final solution. As soon as the precipitate is dissolved, the solution is diluted with hot water to 500 c.c. for each 0.5 gram of iron or steel. The solution is then brought to the boiling-point, when the requisite amount of $NaC_2H_3O_2$ is added, the whole is boiled for a few moments and allowed to settle. When nearly clear, as much as possible of the solution is poured through a ribbed filter, boiling water is added to the precipitate, and the whole again brought to the boil, when it is allowed to settle, and the solution poured through the filter. It is washed again twice by decantation with the addi-

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tion each time of 0 5 c.c. of the same $C_2H_4O_2$; the precipitate is then brought on to the filter and washed with boiling water until free from chlorides. Let the filtrate stand on the steam bath over night. When dry, the residue is taken up in water with addition of about 1 c.c. $C_2H_4O_2$. By this process any iron in the filtrate will be left undissolved and can be filtered off. If I am in a hurry (instead of evaporating to dryness) I add a little Na_2CO_3 solution and evaporate to a suitable volume, the Mn is then precipitated with Br. . . . The Mn is filtered off and weighed as Mn_3O_4. . . . In regard to weighing the Mn as Mn_3O_4 the amount of alkali that it contains is very small, and when the percentage is under 2, the error from that cause is too small to be considered. In fact when at —— I made a series of tests on that subject by weighing the Mn first as Mn_3O_4 and then as $Mn_2P_2O_7$, and found that up to 2 per cent. the difference was very small."

Although this chemist is thus careful in describing the pains he takes to insure correct results, and shows evidence of being entirely scientific in his methods, I am inclined to the opinion that his results are far from accurate. The tests he refers to, as proving the small amount of alkali in the precipitate of Mn_3O_4, I think, were made during his analyses of spiegels, and not of steel. A difference of .057 in duplicate analyses of spiegel may be considered close enough, but I think the majority of steel-works' chemists would not consider it close enough in an analyses of soft steel, which is desired to contain as little manganese as possible, without red-shortness. The majority of evidence in the above list is also against his figures, although they show a noticeable approximation to results Nos. 3, 4, and 5. I will leave a criticism of his method, as he describes it, for other chemists.

J. writes a very brief letter with his results, merely stating that Nos. 19 and 20 were obtained by the acetate of soda and bromine process; Nos. 21 and 22 "by dissolving 19 and 20 in HCl, and proceeding as the HNO_3 and $KClO_3$ method directs;" and Nos. 23 and 24 "by the HNO_3 and $KClO_3$ process, without modifications." Although the duplicate determinations are far from being as close as those of chemists D., F., and G., they give strong indications of the inaccuracy of the acetate and bromine process, as compared with the other; that is, as both are manipulated by this chemist.

K. has been an iron-works chemist for two years. He graduated under Dr. Drown in 1878. In his second result he says the precipitate by phosphate of soda was dissolved in hydrochloric acid,

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nearly neutralized, boiled with acetate of soda, and reprecipitated by microcosmic salt.

L. is one of the most prominent professional chemists in the country, with an excellent reputation for accuracy. The first result, No. 29, is his own; the next two are by his two assistants, all working independently, and without knowledge of each other's results. The method was essentially that described by Mr. A. A. Blair in the reports of the U. S. Testing Board. It is the acetate of soda process, with great precautions taken to insure the freedom of the final precipitate from oxide of iron and alkali.

My general conclusions from this investigation are:

1. That the manganese in this particular plate of steel is not above 0.41 per cent., and is probably between 0.33 and 0.38.

2. That both the acetate and the nitric acid processes are capable of giving correct results, if properly handled, and if proper precautions are taken to insure, first, that all the manganese is precipitated; and, secondly, that the final precipitate is not contaminated with alkali and oxide of iron.

3. That the sources of error in the acetate process are very much larger than in the nitric acid process, and the errors in the former are apt to be so large as to render the analysis utterly untrustworthy and misleading. In this category I would place results Nos. 2, 3, 4, 5, 17, and 18.

4. That the possibilities of error in the acetate process are not yet fully appreciated by many chemists of large experience and reputation.

5. That the whole subject of manganese determinations ought to be made the subject of a reinvestigation by the great body of chemists, to the end of discovering a new, or perfecting an old, method, such that by it any chemist of ordinary ability could obtain results which a manufacturer could depend upon to be accurate within a reasonable limit, say .05 of one per cent.

I must express my thanks to the gentlemen who have kindly aided me in this investigation, some of whom are members of the Institute, although I am not at liberty to give their names.

DISCUSSION.

DR. T. M. DROWN, Easton, Pa.: I am sure that all chemists and steel manufacturers will feel very grateful to Mr. Kent for the presentation of this very valuable "symposium" on manganese deter-

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minations. I think I recognize myself in his paper under the letter "D." The determinations quoted were made, as stated, by my assistant, Mr. P. W. Shimer, and I give in detail the process used by him:

Weigh out 1 to 1.5 grams of the borings into a small beaker, and dissolve in nitric acid (sp. gr. 1.2). Evaporate nearly to dryness, and heat in an air-bath at 140° C. for three to four hours. Redissolve in hydrochloric acid (sp. gr. 1.12); filter into a large beaker, and evaporate the filtrate to a very small bulk. Allow the solution to become cold, and add sodium carbonate solution till a slight permanent precipitate remains after allowing the solution to stand a few minutes. Then add, drop by drop, just enough acetic acid (sp. gr. 1.04) to redissolve this; and, finally, 10 to 12 c.c. more acetic acid and 200 c.c. cold water. 6 to 8 grams of sodium acetate are now added, and, when solution of the acetate is complete, water is poured in until the bulk of the solution is 1.5 liters. Boil for five minutes, allow the precipitate to settle completely, filter through a large ribbed filter, and wash a few times with hot water. The filtrate is evaporated to a small bulk (200 to 300 c.c.), and contains the greater part of the manganese. Throw the precipitate with the filter into the beaker in which the precipitation was made, and add enough hydrochloric acid to redissolve it. After filtering, evaporate the solution to get rid of the excess of acid, and make another basic acetate separation precisely as before. The filtrate from this second precipitation contains the remainder of the manganese, and is likewise evaporated to a small bulk. If, in evaporating either of the manganese filtrates, a precipitate separates, this must be filtered off, dissolved in hydrochloric acid, and a basic acetate separation made; the filtrate is added to the main filtrates. The combined filtrates are concentrated to a bulk of 300 c.c. Bromine-water is added to the hot solution, which need not be heated to boiling. The solution is kept hot and bromine-water added occasionally for two or three hours, water being added to replace that lost by evaporation. The precipitated oxide of manganese is filtered, washed thoroughly with hot water, dried, ignited, and weighed as Mn_3O_4. When much manganese is present, the precipitate by bromine is redissolved in hydrochloric acid, and precipitated by sodium phosphate with the usual precautions.

Since these analyses were made Mr. Shimer has investigated the effect of the filter-paper on the determinations. Two filters were used in the process, of unwashed Swedish (No. 2) paper, and he has found that this paper contains enough manganese to appreciably

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affect the result when working on one gram of steel. By working a blank analysis a precipitate was obtained by bromine, which had appreciable weight, and gave a manganese reaction. Further experiments showed that the manganese in solution had its origin in the filter-paper. It would, therefore, seem necessary, where great accuracy is required, to make a "dummy" analysis for a correction of the amount of manganese found. In the case under consideration this correction would have probably reduced the percentage of manganese from 0.45 per cent. to 0.40 per cent. Subsequent determinations of the manganese in this steel were made by Mr. Shimer by the method described by Mr. Ford (nitric acid and potassium chlorate) with the following results: 0.387 and 0.390 per cent.

DR. C. B. DUDLEY, Altoona, Pa.: The results obtained by Mr. Kent on the determinations of manganese, in the same sample of steel, by different chemists, are certainly very interesting, and show, as it seems to me, that there is great need of the matter being thoroughly investigated, and some method agreed upon which shall, in different hands, give uniform results. The method which I follow is in use at the Sheffield Scientific School at New Haven, unless their practice has been modified within two or three years. I make no claim to originality in it in any place whatever. The method is as follows:

Work on three grams of steel. Dissolve in aqua regia (2 parts HCl to 1 part HNO_3), using 50 c.c., and evaporate to dryness. Take up in 50 c.c. hydrochloric acid and evaporate one-half or two-thirds of this. Allow the solution to cool, dilute to about 150 c.c. and filter. Next make a basic acetate separation of the iron as follows. Nearly neutralize with carbonate of soda, then add 30 c.c. of acetic acid and 25 grams of acetate of soda; dilute to about a liter, and boil for about three minutes. Then pour the solution and precipitate into a tall graduated beaker, holding about 1800 c.c.; fill up with warm water to about that point; mix thoroughly by stirring, and allow the precipitate to subside. When it has well settled siphon off three-fifths or two-thirds of the clear solution and evaporate this down to about 300 or 400 c.c. Next neutralize with carbonate of soda, and then add caustic soda and boil a few minutes. This throws down all the metallic oxides in the solution. Filter, wash thoroughly, and dissolve the precipitate in the smallest amount of concentrated hydrochloric acid. This may be done by spreading the filter out on a large watch-glass and dropping the acid on to it,

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or by putting the filter in a beaker and adding the acid. After solution is complete add a few cubic centimeters of water and filter, washing well. Then make a second basic acetate separation, to remove the last traces of iron. In this separation the addition of carbonate of soda is carried a little past the neutral point, so as to obtain a small precipitate. If there is not enough iron present to give a precipitate a drop of chloride of iron is added. The precipitate is dissolved in dilute hydrochloric acid, and enough acid added so that there is an amount about equal to one drop of free concentrated hydrochloric acid in the solution. The volume of the solution need not be over 50 c.c. to 75 c.c. Now add 2 grams of acetate of soda and boil. Filter into a flask holding about a liter, dilute to nearly that volume, warm to about 80° C., and add bromine-water to distinct red coloration. The precipitate forms after a short time, and, if desired, the solution may be allowed to stand at a moderate temperature—say from 30° to 40° C.—until the bromine has disappeared, before filtration. Filter and wash thoroughly with hot water, then test the filtrate with more acetate of soda and bromine-water to see if the manganese is all down. If any more comes down it of course should be added to the first. The precipitate is dried, ignited over the blast-lamp, and weighed as Mn_3O_4.

In my judgment the two basic acetate separations in the method described above are the critical points in the operation. In the first separation the main point is not to lose any manganese. It is immaterial whether the iron is all separated or not, since there is another operation for that purpose. But if manganese is lost at this point an inevitable error of course results. In this method the presence of acetic acid is relied on to prevent the loss of manganese. I am aware that there are good chemists who neutralize the solution and do not use acetic acid at this point. But the results of direct experiments made at the Sheffield Scientific School go to show that if there is not enough free acetic acid present, with a single separation, loss of manganese results. On the other hand, the same experiments show that if the amount of free acetic acid is too great the iron is not all separated. In the first separation, therefore, since it is immaterial whether all the iron is separated or not, it is only essential that there be enough acetic acid present to prevent loss of manganese. In a solution of about 700 to 800 c.c. volume, it is believed, as the result of experiment, that 30 c.c. of acetic acid is sufficient to accomplish this result. The second basic acetate separation is even more critical than the first. Here there must be acetic acid

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enough present to prevent loss of manganese, and not so much as to hold up the iron. As the result of considerable experience and a number of tests, I am inclined to think that if the directions given above are closely followed, the errors in either direction will be small. I have a number of times examined the precipitate of iron from this separation for manganese and have never found any; and, on the other hand, I have repeatedly examined the manganese oxide, after weighing, for iron, and only rarely have I found it.

These remarks apply to the determination of manganese in iron and steel, where the manganese rarely amounts to one per cent. I have had almost no experience with spiegels, and cannot say how well the directions given apply to them. It may be thought that in taking an aliquot part of the solution from the tall graduated beaker the space occupied by the precipitate in the bottom of the beaker introduces some error. But direct experiments made in the Sheffield School show that the error from this cause is no greater than that which arises where the basic acetate precipitate is filtered, owing to the difficulty of completely washing the large iron precipitate.

I may add that I have made a few experiments with the method described by Mr. Ford and have obtained results agreeing very closely with those obtained by the above method.

NOTE ON THE FALLING CLIFF ZINC MINE.

BY F. P. DEWEY, WASHINGTON, D. C.

THE Falling Cliff Mine adjoins on the west the Bertha Mine, from which a large amount of first-class ore has been taken, producing the purest zinc known to commerce. The two mines are in the same hill, Bertha being on the northern slope and Falling Cliff on the top and opposite slope. The formation is No. 2 limestone. Although considerable exploration has been done by numerous shafts and tunnels (there being over six hundred feet of the latter), no satisfactory determination of the dip and strike of the vein could be made on account of its contortions, the ore descending from the top to the bottom of the tunnels and rising again in very short distances; but enough has been done to indicate a very large mass of

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ore. The general character of the ore is similar to that in the Bertha Mine, being a silico-carbonate, with, perhaps, a larger proportion of carbonate than in the Bertha. The quality is excellent, as shown by the following analyses. No. 1 and No. 2 are from different parts of the same shaft, which descended through twenty feet of ore without bottoming on rock; No. 3 is from a second shaft:

	I.	II.	III.
Silica,	24.47	7.07	4.83
Ferric oxide,	2.10	1.44	4.07
Alumina,	1.24	0.66	0 14
Manganese oxide,	0 16	0.11	0.21
Zinc oxide,	61.81	61.99	59 88
Lime,	0.53	0 16	0.57
Magnesia,	0.21	0.21	0.35
Carbonic acid,	1.80	25 88	29.07
Water,	8.27	2.58	1.46
	100.62	100.10	100.58

Very careful tests failed to detect any tin, arsenic, antimony, lead, copper, bismuth, or cadmium in the ore, although by assay a small amount of silver was found in each, and the gangues of No. 1 and No. 2 contained a little lead and considerable barytes.

The development of this mine is very much retarded by the lack of transportation facilities, the nearest point on a railway being Martin's Station, on the Norfolk and Western Railroad, fifteen miles away; but it is hoped that this drawback will soon be removed.

ON THE FILTRATION OF WATER FOR INDUSTRIAL PURPOSES.

BY P. BARNES, SPRINGFIELD, ILLINOIS.

THE complete and accurate filtration of water (if the word accurate may be thus used) for the feeding of boilers, and for many similar industrial purposes, although somewhat practiced both at home and abroad, has been by no means common. Even if the exact line cannot be defined at which filtration begins to be called for, and will be found profitable, it is certain that in a large number of cases it may be employed with real advantage in the economy of fuel, and also in the greater durability of the boiler or other form of apparatus in

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connection with which the water may be used. It may be carried on without any attendant disadvantage of costly apparatus, or of complex fixtures of any kind, which are liable to get out of repair, perhaps at the time, of all others, when their service is most urgently needed.

No special form of apparatus need be mentioned in this paper, nor need there be any reference to other kinds or types of fixtures than the time-honored device of an open sand-filled tank or basin. A brief discussion of these familiar details may serve to set forth the principles involved, and the entire practicability of applying them to the water-supply of nearly all kinds of industrial work. The general character of this discussion is the more desirable because the waters of different localities vary so widely, and so also do the materials which, being found near at hand, can alone be used profitably in the filtering apparatus.

It is too often supposed that a filter of any kind is, and must necessarily be, only a hopeless annoyance and perplexity to the workmen who have charge of it; but this comes chiefly from using, or attempting to use, a filter far too small for the work, or else from some error in arrangement that ought to be discovered and corrected. Sometimes the effort is made to combine the work of filtration with that of heating the water, if it be used for boilers, or possibly with the storage of the water in some tank of trifling capacity. In many cases the filter is set in some inclosed space, as an engine or boiler-room, where the interruption of cleaning becomes a genuine annoyance to all concerned.

If a simple mechanical sifting alone be attempted, and in most cases this is all that can be brought within the limit of admissible cost, then the problem becomes really a very elementary one, and need not involve any more than the plainest forms of apparatus, and the simplest kind of manipulation for the securing of useful and very perfect results. These plain and even rude appliances are in fact the ones which alone can endure the inevitable rough handling and all the usual exigencies of this class of work.

This discussion should include:

1. A description of the basin or inclosure for holding the filtering medium, and, if needful, for the storage of the water after the filtration.

2. A note of the method of putting in the materials used for the

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filter-bed, as adapted to the wide variety from which selection may have to be made, and also to the ordinary character of the water to be treated.

3. An explanation of the simple method of working under ordinary circumstances.

4. A description of the method to be employed in cleaning the filter, this being almost the sole working cost of the operation, for the first cost of construction may be kept within so moderate a limit that the interest charge upon it will be trifling.

1. The filter-basin or tank should be divided at least into two parts, so that one may be at all times ready for service. If the water is likely sometimes to be heavily charged with mud, a larger number of compartments become needful, for the time needed for cleaning is thus increased, and it is then all the more desirable that the apparatus in which the water is to be used shall be always definitely protected from injury by the mud brought in from the source of supply. These compartments should be of ample size, for the filtering process to be perfect must be carried on slowly. The mechanical sifting out of the fine impurities can only be done by passing the water through a fine-grained or dense medium, and hence the movement of the water through this medium must necessarily be slow. If space can be found, very large basins are desirable, although useful results are obtained in tanks of quite limited size. The outline may suit the space which can be devoted to the basin or tank, being either rectangular or circular as may be needful.

The choice of location for the filter-bed may be made to suit the exigencies of any given case. The basins may be put at the source of supply, perhaps at a distance from the works, the clean water alone being brought through the pipes. On some rivers the material of the bank itself is found to be an admirable filtering medium, so that the cutting or sinking of a plain trench in this material fills the whole requirement. Some filter "galleries," on an extended scale, have been thus made with excellent results. In some cases wells have been sunk by the side of a canal, and from them very pure water has been drawn in ample quantity, which, if taken direct from the muddy canal, would have been subject to a water tax, as well as wholly unfit for the required purpose.

If an open basin be employed, a screen should be so placed as to intercept leaves and similar material, so that they may not be widely scattered and more troublesome to remove. The inlet-pipe should be led in above the usual water-level, so that the amount,

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and character as to cleanliness of the supply may be constantly observed. The outlet is necessarily led away at the bottom of the tank, and it should have, at the nearest practicable point to the filter, an open discharge, from one pipe into another, or into a storage reservoir, so that the purity and the amount of flow may be approximately noted at a glance. The volume of water passing the filter will obviously diminish as the sand surface becomes saturated or filled with mud or silt, and thus, by the flow from an open outlet, the comparative condition of the filter may at once be noted.

2. The material and method of filling must be suited to the water which is passing. One grade of fineness of the surface may be quite sufficient at one season of the year and doubtful or imperfect at another. At the bottom of the basin a layer of tiles, or coarsely broken rock, should be laid, so that an ample and uniform outlet may be had for the water from all parts of the surface area. This tile bottom may serve also a useful purpose in the storage-room, which it furnishes for the clean water. For the next layer coarsely broken brick, ore, slag, or coke should be used, or, indeed, any material which will not become softened by soaking in the water, and which is of a rather rough or angular character in its fracture. The next layers may be of the same material more finely crushed, so that at length, at the upper surface, the whole shall be nearly or quite like a fine sand, such as will pass a forty or sixty mesh screen. This method of filling affords in the best possible way the opportunity of correcting any imperfect working, for, by changing from one filter-bed to the alternate, the first may be repacked, or a finer material may be put on as needed, until the required result is reached.

At any iron works one of the best of all materials is usually to be found, viz., hard coke, which, when crushed fine, resembles very closely the animal charcoal so universally employed for the finest filtering, either for household service or for the higher class of manufacturing. In few words, almost anything can be made to serve as filtering material which can be crushed fine enough to act as a mechanical barrier to the sediment or mud borne by the water, and there are very few works or regions in which some kind of rock cannot be obtained.

3. In the working of the filter, the uniform downward soaking away of the water alone needs to be provided for. For this purpose the water should be as uniformly distributed as possible, and should be led on to the filter very quietly. To prevent any disturbance of the fine sand surface, a quantity of coarser rock or sand should be

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spread to break the fall or flow of the entering water, or a simple timber or plank apron may be laid. This method of filtration is obviously suited to the cleansing of any quantity of water, whether small or large, up to the maximum capacity of the filter. The smallest quantity is as perfectly dealt with as the largest, and the whole apparatus need suffer no material injury from any probable standing for a time unused.

In some climates an open-basin filter would be subject to freezing, and thus to a complete stopping. As soon, however, as the area or number of basins required for any given establishment has been determined, a simple shed or inclosing roof can be erected at no great cost, which, with the constant flow of the water, will be found ample to prevent obstruction from freezing. In extreme cases the tanks or basins must be fully inclosed in frost-proof casings, or placed inside of some permanent building which can afford the needful protection.

No method of dealing with the waste water from a manufacturing establishment is so effective as filtration, so far as freeing it from impurities held in suspension are concerned. When elements held in solution must be removed or neutralized, the problem becomes a difficult one, and its solution, in the large majority of cases, quite passes the limit of admissible cost.

4. The gradual diminution of the outward flow from the filter-bed, at the open discharge pipe referred to, gives all needed warning of the choking or filling up of the surface of the sand stratum at the top. When this has reached the fixed limit, the flow of water is turned into one of the duplicate basins, and the first is suffered to become empty and to dry away for cleaning. As a rule, the mud and other obstructing sediment will not be found to penetrate deeply, and hence the removal by scraping or shovelling of a thin layer from the surface, of from one to three inches, will be found to restore quite fully the flow of water when it is again turned through the filter. Care must be taken in this shovelling or scraping that none of the silt material is rammed or "puddled" into the crevices of the sand which remains, for few things of its kind are more impervious to still water than a stratum of "puddled" clay or similar material. If time enough be taken to let the water soak away quite completely from the filling, then the saturated surface can be very readily shovelled off and removed. More of the surface material can then be spread, or the water turned on at once, in case the top layer was originally made thick enough to permit several cleansings without

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removal or replenishing. The sand may be washed and returned if it be at all in scanty supply; but if crushed coke be used, its rough surfaces will eventually become so charged or coated with mud as to render it unfit for use.

It has been remarked that the cost of this cleaning is really the sole working expense attending the use of this class of filtering apparatus, and this cost need not be great, or indeed more than quite trifling. The filter must be of the primitive type thus described in order that the common labor, which alone can be charged with the detail of such things, shall make no mistake in the refilling or the cleaning required.

An important though indirect advantage attending the use of a filter which has no connection with the work of heating the water treated in it, is that the laying off for cleaning may be done at any time, provided only that a separate compartment is so arranged that the flow may be turned through it without any delay. It is obvious enough that duplicate filter-heaters may be provided, but as a rule they are not, and hence the needed cleaning of the filter compartment must be done when the heater can be spared or is idle, as on a Sunday. This necessity is liable to lead to the running of the filter longer than it should be run, and to a general haste and imperfect cleaning when finally it is attempted. This ends at length, or is very likely to, in an imperfect working of the whole apparatus, and a complete abandonment of the attempt to filter the water at all. If, on the other hand, ample filtering appliances are provided, of the elementary type described, then the barrier thus erected for the protection of the higher classes of apparatus, from sand and débris of all kinds, is rendered very complete and permanent.

Sometimes, too, an unexpected deluge of mud is brought in through the water-supply, which, in a very short time, and almost wholly without notice, fills up solid the pipes, pumps, and heaters, and even finds its way into tuyere pipes and into boilers in hurtful quantities. Against such damage as this, no guard can be maintained so effective as that of an open filter of ample area and fitted with these plain attachments. If the water needed for boilers is at all charged with oily matter, a good sand filter may be relied upon to remove a large part of this hurtful element, which, in many instances, has led to the formation in the boiler of a flocculent deposit upon the more highly heated plates, and to their serious injury by its non-conducting power.

Careful attention has been given to this subject by railroad mana-

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gers for the protection of their locomotives, but, as the quantity consumed in this service is comparatively small, an important part of the purification of the water may be effected by giving it time to settle in a tank. There still remains, however, even after the matter mechanically suspended has been wholly removed, the frequent presence of salts of lime held in solution, and the incrustations due to these are often exceedingly troublesome to deal with. They are such, too, as cannot be eliminated except by heating, and then only in part; but these methods of purification at best are costly, and quite apart from the purpose of the present paper.

In the first study of a location for a large works, the quantity of water is usually the first question to be considered, while the quality is held as secondary. This may be the more safely permitted if care be taken, in the outfit of the works, to provide the filtering fixtures needed to restore the quality of the water, if doubtful or bad, to a normal and reasonable standard. In any case, the cost of this part of the general apparatus may very justly be taken as an investment for the insurance of the more costly parts of the machinery against one of the causes of injury, from which delay and damage may result. In all the strictly modern works improved appliances are to be found in many of the departments, and improved methods of working are continually sought for and adopted. The use of filtered water, when it can be had at so trifling and quite nominal a cost, is one of these steps in advance in the management of the great masses of steam and other machinery of the present day, and it is worthy of a more careful consideration and more frequent adoption than it has received. With the tendency to constant advance in steam pressures, in temperatures in and around furnace pipes and fixtures, and in the crowding and driving of hydraulic machinery in general, there is need of the use of the very best water supply that can be had, for the best, whether from natural or artificial sources, is in no way too good for the intense service required

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PROCEEDINGS

OF THE

HARRISBURG, PA., MEETING,

OCTOBER, 1881.

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LOCAL COMMITTEE OF ARRANGEMENTS.

Henry McCormick, *Chairman;* David Watts, *Secretary;* H. H. Campbell, A S. McCreath, S H. Chauvenet, C. E. Stafford, George S. Comstock, Jones Wister, E. C. Felton, F. W. Wood, Harvey Fisher.

CITIZENS' RECEPTION COMMITTEE.

Governor H. M. Hoyt, Hon. John C. Herman, Hon. Simon Cameron, Hon. J. D. Cameron, W T Hildrup, Charles L. Bailey, W. W. Jennings, Lane S. Hart, H. H. Carter, Gilliard Dock, T. T Wierman, Jr., James Boyd, D L. Jauss, Dr. T. J. Dunott, S. C. Gilbert, William J Rose, James Lynah, Dr. H. B Buehler, William B. Lamberton, John Wister, G. M. McCauley, David Fleming, John Q. Denney, M. E. Olmsted, H. S Gross, Henry Gilbert, John B McPherson, Lyman D. Gilbert, F. W. Forman, L. S. Bent, A. J. Dull, F. R. Leib, Dr. G. W Reily, James McCormick.

The opening session of the meeting was held in the hall of the Young Men's Christian Association, on Tuesday evening, October 25th. Mr. Jones Wister, of the Local Committee of Arrangements, introduced the Hon. John C. Herman, mayor, who, in a brief address, extended to the members present a welcome to the city of Harrisburg; Lieutenant-Governor Stone made an address of welcome on behalf of Governor Hoyt and the Commonwealth of Pennsylvania.

President Metcalf responded, on behalf of the Institute, to the cordial addresses of the mayor and lieutenant-governor.

The following persons proposed for members and associates of the Institute, and recommended by the Council, were unanimously elected :*

MEMBERS.

William F. Aldrich,	Montevallo, Shelby Co., Ala.
George H Blake,	Steelton, Dauphin Co., Pa.
L. Bertram Cady,	Salisbury, N. C.
John B. Church,	Pottsville, Pa.
Walter S. Church,	Pottsville, Pa.
Frank L Clark,	Pittsburgh, Pa.

* In the following list are included those elected at a subsequent session of this meeting.

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Thomas H. Clark,	Mansfield Valley, Allegheny Co., Pa.
George M. Davidson, Jr.,	Johnstown, Cambria Co., Pa.
Edward S. Davies,	Pottstown, Pa.
Henry C. Davis,	Philadelphia.
John M. Deslogc,	Bonne Terre, Mo.
John Endey,	Friedensville, Lehigh Co., Pa.
C. B. Finley,	Huntingdon, Pa.
John J. Fisher,	Allentown, Pa.
Henry Fulton,	Ward, Boulder Co., Colo.
William R. George,	Dover, New Jersey.
William Glenn,	South Stafford, Vt.
David S. Goddard,	Steelton, Dauphin Co., Pa.
Henry S. Gross,	Harrisburg, Pa.
James F. Hall,	Tarrytown, N. Y.
Professor Edward Hart,	Easton, Pa.
Henry Y. Haws,	Johnstown, Pa.
E. P Hemenway,	Johnstown, Pa.
F. C. Holman,	Mansfield Valley, Allegheny Co., Pa.
Griffith Jones,	Pottstown, Pa.
Hugh Kennedy,	Etna, Allegheny Co., Pa.
Daniel King,	Pine Grove Furnace, Cumberland Co., Pa.
Frank J. Kramer,	Parryville, Carbon Co , Pa.
John C. Long,	Richmond Furnace, Franklin Co., Pa.
John A. McGuffin,	Sewell Depot, C. & O. Ry., W. Va.
William M. Marple,	Clinton, N. Y.
Joseph Morgan, Jr.,	Johnstown, Pa.
Henry G. Morse,	Youngstown, Ohio.
Knight Neftel,	New York City.
Thomas B. Nichols,	Bogota, U. S. of C., S. A.
William J. Nicolls,	Snow Shoe, Centre Co., Pa.
Webster Norris,	Johnstown, Pa.
H. C. Perkins,	North Bloomfield, Nevada Co., Cal.
Robert Pitcairn,	Pittsburgh, Pa.
E. Windsor Richards,	Middlesbrough, England.
Thomas A. Roberts,	Bedford, Pa.
H. Schulze-Berge,	Pittsburgh, Pa.
I. M. Scott,	San Francisco, Cal.
Edward. H. Sears,	Collinsville, Conn.
Albert Spies,	Jersey City, N. J.
Charles A. Stetefeldt,	New York City.
John M. Stinson,	Harrisburg, Pa.
Fred. W. Taylor,	Smithsonian Inst'n, Washington, D. C.
Robert M. Thompson,	New York City.
J. N. Tilemann,	Natrona, Pa.
H. C. Torrance,	Braddock, Allegheny Co., Pa.
John Townsend,	Steelton, Dauphin Co., Pa.
Magnus Troilius,	London, England.
Alfred Tucker,	Philadelphia.
William R. Walker,	Chicago, Ill.
H. A. Wheeler,	New York City.

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Joseph C. Whitaker,	Steelton, Dauphin, Co., Pa.
J. Schall Wilhelm,	Cornwall, Lebanon Co , Pa.
D. H. Williams,	Homestead, Allegheny Co., Pa.
Arthur Winslow,	Philadelphia.
William J. Wood,	Collinsville, Conn.
Edward H. Woodward,	New York City.
James Witherspoon,	Seneca Falls, N. Y.

ASSOCIATES.

Victor M. Braschi,	New York City.
Samuel F. Burnet,	Carondelet, Mo.
H. B. Burt,	Philadelphia.
Albert Calman,	New York City.
Hunter Eckert,	Reading, Pa.
Thomas H. Hulbert,	Washington, Ga.
Frank Julian,	St. Louis, Mo.
Daniel J. Leary,	Brooklyn, N. Y.
Joseph D. Long,	Pittsburgh, Pa.
W. S. Mackintosh,	Pittsburgh, Pa.
Joseph T. Monell,	Kansas City, Mo.
James H. Murdock,	Pittsburgh, Pa.
L. H. Ritterskamp,	St. Louis, Mo.
William J. Rose,	Harrisburg, Pa.
S. Bent Russell,	St. Louis, Mo.
Edward Young,	New York City.

The status of the following associates was changed to member: E. V. McCandless, S. S. Hartranft, Joseph Hartshorne, and T. B. Stearns.

Mr. S. H. Chauvenet, of Harrisburg, read a paper on The Industries of Harrisburg.

Mr. E. Windsor Richards, of Middlesbrough, England, gave, by request of the Council of the Institute, a description of the origin, progress, and present condition of the basic process in England.

The second session was held on Wednesday morning, when the following papers were read:

The Available Tonnage of the Bituminous Coal-fields of Pennsylvania, by H. Martyn Chance, M.D., of Philadelphia.

The Flannery Boiler-setting for the Prevention of Smoke, by Charles A. Ashburner, of Philadelphia.

Mr. A. C. Rand called attention to a new compound for blasting purposes, composed of two ingredients, each non-explosive by itself, to be mixed immediately before use.

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At the conclusion of this session an excursion was made, by special train provided by the Pennsylvania Railroad Company, to the following works: The Pennsylvania Steel Works, Lochiel Rolling Mill, Paxton Furnaces, Paxton Rolling Mill, Central Iron Works, Chesapeake Nail Works, and Harrisburg Car Manufacturing Works. An exhibition of the effect of the blasting compound, described by Mr. Rand at the morning session, was made at the limestone quarry adjoining the Paxton Furnaces. At Steelton the members were invited to lunch by the Pennsylvania Steel Company.

In the evening there was a reception at the Governor's mansion, given by the citizens and ladies of Harrisburg to the visiting members and accompanying ladies.

On Thursday an excursion was made by special train, provided by the Cumberland Valley Railroad, over the Cumberland Valley, the Dillsburg and Mechanicsburg, Harrisburg and Potomac, and South Mountain railroads. Opportunity was afforded on this trip to visit the hematite ore mines of the Philadelphia and Reading Coal and Iron Company, the Carlisle Iron Works, the hematite ore mines on the line of the South Mountain Railroad, Laurel Forge, and Pine Grove Furnace. Mr. J. C. Fuller kindly entertained the party at his house at Pine Grove. On the return to Harrisburg the Indian School at Carlisle was visited, under the guidance of Captain Pratt, U. S. A., and his teachers.

The third session was held on Thursday evening. Mr. Troilius's paper on Chemical Methods for Analyzing Rail Steel was read and discussed.

Written communications on this paper were read (in absence of the authors) from Messrs. Gayley and Farrell, Emmerton, Dewey, Mackintosh, Wright, and Cabot.

There were also read at this session the following papers:

The Analysis of Iron Ores containing both Titanic and Phosphoric Acids, by T. M. Drown and P. W. Shimer, of Easton, Pa.

The Great Flat-Top Coal-field of New River in Virginia and West Virginia, by Jed Hotchkiss, of Staunton, Va.

The fourth session was held on Friday morning. Papers were read on a Test Support for the English Cupellation Furnace, by F. C. Blake, of Mansfield Valley, Pa., and on Improvements in Firebrick Stoves, by Julian Kennedy, of the Edgar Thomson Steel Works, of Pittsburgh, Pa.

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General J. F. Hall exhibited, by request, a series of lithographic plates illustrating Timby's method of harbor defence by revolving turrets.

The following papers were read by title:

Method of Assaying Silver Bullion, by F. C. Blake, of Mansfield Valley, Pa.

Notes on the Geology and Mineralogy of San Juan County, Colorado, by Theodore B. Comstock, of Eureka, Colorado.

The Analysis of Statistics, Second Paper, by A. W. Hale, of New York.

The Chrysolite Mine Fire, by C. M. Rolker, of Leadville, Colorado.

The Presence of Tellurium in some Commercial Coppers, by Dr. T. Egleston, of New York.

The Binding of In-walls of Blast Furnaces, by S. H. Chauvenet, of Harrisburg.

The following resolutions were offered and unanimously adopted:

WHEREAS, The American Institute of Mining Engineers has been the recipient of unusual attention and hospitalities in Harrisburg and vicinity, which call for grateful recognition.

Resolved, That while we realize the unsatisfactory character of mere formal resolutions of thanks, which can at best but imperfectly express our sense of obligations, we desire to place upon our minutes an expression of our indebtedness to Governor and Mrs. Hoyt, the citizens and ladies of Harrisburg, Mr. J. C. Fuller, of Pine Grove, the Cornwall Ore Bank Company, and the President and officers of the Pennsylvania Steel Company, for their charming and hospitable entertainments; to the Pennsylvania, Philadelphia and Reading, Cumberland Valley, South Mountain, Harrisburg and Potomac, Mechanicsburg and Dillsburg, and the Cornwall railroad companies for the favors of transportation on special trains; to the proprietors and officers of mines and works for the many favors shown to the Institute, and to the Local Committee for their admirable arrangements and thoughtful solicitude for the pleasure and profit of the visiting members.

Resolved, That the Secretary of the Institute be instructed to give suitable expression to our sentiments in letters of acknowledgment and thanks.

Mr. Birkinbine gave notice that he would offer an amendment to Rule VI at the next annual meeting.

The President then announced that, in accordance with the programme, the meeting was formally adjourned; but that there would be a supplementary session in the evening, when Mr. T. F. Witherbee, who was unable to arrive in time for the regular sessions, would read his paper on The Use of High Explosives in the Blast Furnace.

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At the conclusion of the morning session an excursion was made by special train, provided by the Philadelphia and Reading Railroad Company, to the new Colebrook furnaces, and the Cornwall Ore Banks near Lebanon. The party were kindly entertained at lunch in the Opera House in Lebanon by the Cornwall Ore Bank Company.

In the evening the members and their ladies were invited by the Pennsylvania Steel Company to a complimentary banquet at the Lochiel House.

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PAPERS

OF THE

HARRISBURG, PA., MEETING,

OCTOBER, 1881.

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THE INDUSTRIES OF HARRISBURG.

BY S. H. CHAUVENET, HARRISBURG, PA.

HARRISBURG is situated on the Pennsylvania Railroad, one hundred and five miles from Philadelphia, two hundred and forty-eight miles from Pittsburgh, and ninety miles from Baltimore, and has running through it the Pennsylvania, Northern Central, Philadelphia and Reading, and Cumberland Valley Railroads, and the Pennsylvania Canal. Surrounded by a thickly settled farming country, from which to draw native labor, within easy distance of anthracite and bituminous coal, with ores and limestone near at hand, and with the Susquehanna River as a never-failing water supply, Harrisburg has advantages for manufacturing which warrant the investment of the capital that has already been made, and has a future as a manufacturing city second only to Pittsburgh and Philadelphia.

THE PENNSYLVANIA STEEL COMPANY,

L. S. BENT, SUPERINTENDENT.

The works of this company, the largest in Harrisburg, lie between the Pennsylvania and the Philadelphia and Reading Railroads, on the Pennsylvania Canal, and are essentially devoted to the manufacture of Bessemer steel rails. Capital stock, $2,000,000; invested in business, $5,000,000; wages per month, $80,000; employs 2000 men; capacity, 100,000 tons of rails per year, which is being increased to 130,000 tons.

The plant, as it now stands, comprises five Bessemer converters, two 7-ton and three 8-ton converters, two 15-ton open-hearth furnaces in operation, and two 30-ton open-hearth furnaces in course of construction, one blooming mill, one rail mill, seven steam hammers, two blast furnaces in operation, two blast furnaces in course of construction, foundry, pattern shop, machine shop, blacksmith shop, and frog shop, and merchant mill in course of construction.

Bessemer No. 1 was built in 1865, with two 7-ton converters, 2 spiegel cupolas, 3 feet diameter, and 3 iron cupolas 6′ 6″ diameter,

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and has a capacity of 500 tons in 24 hours. The blowing engine is a horizontal condensing engine, with two steam cylinders, 40″ x 60″, and two blowing cylinders, 54″ x 60.″ Pressure of blast, from 20 to 25 pounds.

Bessemer No. 2 was built in 1881. It has three 8-ton converters, served by two hydraulic ladle cranes, in two casting-pits, and six hydraulic cranes for setting and drawing moulds, handling bottoms, etc. The hydraulic pressure is 300 pounds per square inch. The blowing engine is a compound horizontal, with a high pressure cylinder, 25″ x 70″, and low pressure, 50″ x 70″, with separate air-pump condensers, and also a Bulkley condenser attached. Pressure of blast, 25 to 30 pounds. This engine was built in the Pennsylvania Steel Company's shops. There are four iron cupolas, 6′ 6″ diameter, and four spiegel cupolas, 3′ 0″ diameter, blown by two No. 7 Baker blowers, or two three-cylinder blowing engines.

The capacity of this Bessemer has not yet been determined, as it has only been in operation two weeks. There are many points of improvement over the old Bessemer, which cannot be described in this paper. All the castings, boilers, roofs, wrought-iron work, and engines of this plant were made and erected by the Pennsylvania Steel Company.

The Blooming Train is three high; rolls 34″ in diameter, driven by a vertical condensing engine, 44″ x 54″ cylinder. The capacity of this mill has never been determined, but is easily 600 tons in 24 hours. The ingots are delivered hot to the blooming mill from the Bessemer, and charged into four Siemens heating furnaces, six ingots being a charge for each furnace. The ingots are 14 inches square and make four rails each. The blooms are cut under a 4-ton steam hammer (Sellers), and are loaded by a hydraulic crane on buggies, which are pulled by a water engine to the rail mill.

The Rail Train is three high; rolls 23″ diameter, driven by a 40″ x 60″ engine, with Bulkley condenser attached. This train has rolled 1916 rails in 24 hours. The saw-train is Gustin's patent. Two straightening presses and four drill presses handle the rails as fast as rolled.

The Open Hearth Furnaces, built in 1875, consisted of two 6-ton furnaces, which were enlarged later to 15-ton capacity. The new open-hearth furnaces in course of construction are each 30-ton. Each furnace has a casting-pit, and the two are served by five hydraulic cranes.

A 14-ton Steam Hammer is placed between the blooming mill and

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rail mill. Under it heavy shafts, cross-heads, and piston rods are forged. When not in use for heavy work it hammers special steel into slabs and billets.

A 4-ton Hammer, adjoining the blooming mill, and a 1-ton hammer in the rail mill are used almost exclusively for slabs and billets.

The Foundry, 60′ x 225′, has two cupolas, 5′ 0″ diameter, two core ovens, and five 15-ton steam cranes. All ingot moulds are made here and all castings for repairs and new work. The capacity of the foundry is 40 tons of finished castings a day.

The Pattern Shop has two circular saws, one Daniels planer, one hand planer, a bandsaw, and one lathe, and bench room for fourteen men.

The Machine Shop is 75′ x 230′, and contains thirteen lathes, from 96″ to 10″; five planers, which take from 8′ square to 20″ square; one 48″ boring lathe, one 84″ boring and turning machine, three 10′ radial drills, two drilling machines, two shapers, two slotting machines, two horizontal boring machines, two bolt cutters, one pipe cutter.

The Blacksmith Shop, 60′ x 75′, contains two 1000-pound steam-hammers, and 14 fires.

The Boiler Shop, 75′ x 127′, contains 3 drill-presses, 2 shears, 1 punching-machine, bending-rolls, and 1 hydraulic riveting-machine. In this shop all steam-boilers, draft-stacks, and iron roofs are built.

The Frog Shop, 60′ x 400′, has a capacity of $30,000 to $40,000 per month in railroad frogs and switches, crossings and interlocking apparatus. It contains 14 planers, 6 drill-presses, 2 slotters, 2 lathes, 1 milling-machine, 1 shaper, 1 pin-machine, 1 steam-hammer, 1 combined punch and shear, 1 single punch, 1 steam-riveter, 1 hydraulic bending-machine, 10 fires, and 1 heating-furnace. A new frog shop is to be put up immediately, 80′ x 400′, with improved facilities.

Blast Furnaces.—No. 1, 14′ x 60′, is blown by a vertical condensing-engine, 84″ blowing cylinder, 48″ stroke; it has 4 pipe-ovens, of Kent's pattern; the fuel used is anthracite coal and coke; the ores are native Pennsylvania, Virginia, and New Jersey, and Spanish and African. The product is 50 to 60 tons per day.

No. 2, 20′ x 76′, is blown by two vertical condensing-engines, 84″ x 48″; 3 Whitwell stoves, 18′ x 60′; fuel and ores are the same as No. 1; product, 840 tons per week. The product of both furnaces is used in the Bessemer.

No. 3 and No. 4 blast-furnaces are each 16′ x 65′. They are to

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be blown by vertical condensing-engines, 70″ x 48″, 2 blowing cylinders to each engine, with a capacity of 22,000 cubic feet of air per minute. These engines are being built by the Pennsylvania Steel Company. Each furnace has 3 Whitwell stoves, 18′ x 60′, and will use the same fuel and ores as Nos. 1 and 2.

A Merchant Mill is in course of construction. The building, 100′ x 400′, will contain one 12-in. roll train, and one 20-in. roll train; the first driven by a horizontal Hughes & Phillips engine, 22″ x 30″, the second by a horizontal Porter-Allen engine, 32″ x 48″.

The Heating Furnaces are Sweet's patent.

The Lochiel Rolling Mill Company,

HENRY M'CORMICK, PRESIDENT.

This company has a capital stock of $400,000, and employs from 550 to 600 men.

The plant consists of a rail-train, 19½″ diameter, driven by a 42″ x 42″ vertical engine. At present it is rolling rails from blooms made by the Pennsylvania Steel Company. The blooms are heated in 8 coal-furnaces, and the capacity of the train is 750 rails in 24 hours.

Puddle-train, 19″ diameter, driven by a 24″ x 48″ engine, with 12 double-puddling furnaces; product, 45 to 50 tons in 24 hours.

Bar-train, 16″ diameter, with 2 heating-furnaces; product, 22 to 25 tons per day.

Guide-train, 9″ diameter, with one heating-furnace; product, 11 to 15 tons per day.

Butt-train, 16″ diameter, with one heating-furnace; product, 18 to 20 tons per day.

The bar, guide, and butt trains are driven by one engine, 32″ by 32″.

Blast Furnace.—One stack, 14′ x 52′, closed top, pipe ovens; fuel, anthracite coal and coke; ores fossil, Cornwall and Dillsburg, and mill cinder; product, 7500 tons per annum.

Iron Works of the McCormick Estate,

HENRY M'CORMICK, TREASURER.

Harrisburg Nail Works were built in 1810, and located at Fairview, directly opposite Harrisburg, on the Northern Central Railway.

The plant consists of 2 roll-trains, 19″ diameter, one puddle and

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one nail plate roll-trains, 9 double puddling-furnaces, 3 heating-furnaces, and 75 nail machines.

The puddle-train is driven by water power, and the nail plate-train by a 200 horse power engine. Product, 10,000 tons of nails, nail-plate, and muck-bar, per year; 350 men and boys are employed.

Paxton Rolling Mill was built in 1869 (John Q. Denny, superintendent). It contains 3 roll-trains, largest 30″ diameter, 5 double furnaces, 5 heating-furnaces, and 1 steam hammer. The product is 9000 tons per year, of boiler, skelp, and tank iron; 200 men are employed.

Paxton Blast Furnaces, McCormick & Co.

No. 1 stack was built in 1855, 14′ x 50′; blown by an 84″ x 84″ engine; pipe ovens in use, but Whitwell stoves are now in course of construction. The product is 10,000 tons per year.

No. 2 stack was built in 1872, 15′ x 60′; blown by 84″ x 84″ engine; 3 Whitwell stoves; fuel, anthracite coal and coke; ores, York County, Pa., magnetic, Cornwall, and fossil ore from Juniata County, Pa. The product is 22,000 tons per year; about 300 men are employed at both furnaces.

Chesapeake Nail Works,

CHARLES L. BAILEY & CO.

Capital invested $500,000; employs 300 men, and pays $165,000 wages annually.

The plant consists of 16 single puddling furnaces, 3 heating furnaces, 3 re-heating furnaces for nail plates, 2 bluing furnaces, 1 annealing furnace for clinch nails, 1 puddle train, 81 nail machines. The annual product is 10,000 tons of muck bar, and 220,000 kegs of nails.

Central Iron Works,

CHARLES L. BAILEY, PRESIDENT.

Capital $200,000; employs 120 men, and pays $100,000 wages annually.

The plant consists of 5 double, and 1 single puddling furnace, 3 heating furnaces, 1 puddle mill, 1 plate train (3 high rolls), 32″ diameter, driven by a 36″ x 60″ engine.

The product is 8000 tons of plate iron and 7000 tons of muck bar. Plates 88″ wide and ordinary lengths, from No. 10 to 1½″ thick are rolled in this mill.

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This firm is now putting in another plate train, 25″ diameter, 3 high, driven by a 25″ x 60″ horizontal engine.

Harrisburg Car Manufacturing Company,

W. T. HILDRUP, SUPERINTENDENT.

Capital stock $500,000; invested in business, $1,000,000; employs 800 men; amount of monthly pay roll $26,000.

The number of cars built daily is 12 to 15, with a daily consumption of 30 tons of charcoal iron, 15 tons of anthracite iron, 40,000 to 45,000 feet of lumber, and 15 tons of bar iron.

The average value of cars is $600, and the total yearly product about $2,500,000.

This company,—one of the most prosperous in Harrisburg,—has a blast furnace, which is being remodelled. Its sawmill is the largest in the city.

Foundry and Machine Department of the Harrisburg Car Manufacturing Co.—In this establishment are manufactured portable and stationary engines, all kinds of foundry and boiler work, and agricultural implements of various descriptions. Its capacity is one portable engine per day, and 10 tons of foundry castings, also an annual production of 500 corn-planters. The number of men employed is 175.

The Wister Blast Furnace.

This furnace was built in 1867, originally 14′ x 45′, but recently altered to 14′ x 60′. It is blown by a 30″ x 48″ horizontal engine, geared to drive two blowing cylinders 72″ x 72″. This engine blows 260 cubic feet of air per stroke, and is capable of running 30 to 35 revolutions per minute, at a pressure of 6 to 7 pounds of blast.

There are three batteries of boilers, two of which give ample steam power. Two Kent 8-inch pipe ovens heat the blast to 1000° or 1100° F. Only one oven is blown through, leaving one in reserve.

Fuel, ¾ anthracite, ¼ coke; ores, Dillsburg, Seizholtzville, Cornwall, and for two years past, about one-third from Spain and other foreign countries. Capacity, 45 tons per day.

The Louise Furnace,

W. H. WOODWARD & DANIEL KING, PROPRIETORS.

This furnace was built in 1875, but was not blown in until 1880. The stack is 10′ x 50′, blown by a 60″ x 60″ horizontal engine, with pipe ovens, built by Raymond & Campbell, of Middletown, Pa.

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Fuel, anthracite coal and coke; ores, hematite from the Cumberland Valley, and Dillsburg magnetite.

The product is from 120 to 130 tons per week.

Hummel, Fendrick & Co.

This firm has lately begun the manufacture of bar iron and tires. The plant consists of a small merchant train and two heating furnaces.

Jackson Manufacturing Company,

JAMES I. CHAMBERLIN, PRESIDENT.

The business of this company, which has recently been reorganized and incorporated, is the manufacture of a wide range of mining implements. At present they manufacture only steel barrows. This product is shipped chiefly into the mining regions of the West, large consignments being constantly made to Pueblo for mining purposes in Colorado. They have also exported quite a large number of barrows.

Capital invested, $50,000; present capacity of works, 15 to 20 steel barrows per day, employing 20 to 25 hands.

Harrisburg Chain Works,

JOSHUA W. JONES, PROPRIETOR.

This industry has been but recently established in Harrisburg, and the above works are not yet fully completed. At present only four furnaces are in operation, but eight others will soon be erected. The principal product will be chain bale-ties, and the capacity of the works is estimated at 3000 per month. A small Baxter engine is employed to drive a fan for fires, and an oven (8′ x 2′ x 6′) is used for japanning the chains. Twelve men are employed.

Eagle Works.

This establishment is owned by Mr. W. O. Hickok, and has been in operation about 25 or 30 years. It embraces a machine shop fitted up for doing all kinds of machine work, an iron foundry, a brass foundry, and a wood-work shop, and gives employment to from 60 to 120 men. It has a large local trade; but its principal product is a class of machine work,—ruling machines, ruling pens, sawing machines, press boards, table shears, etc.,—that is extensively sold in Europe, South America, Cuba, and Australia.

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Harrisburg Steam Boiler Works.

These works are owned and operated by Robert Tippett's Sons. They were built in 1863 by Robert Tippett. Their principal business is the manufacture of steam boilers, furnace work, stacks, etc. They ship punched and shaped iron to Ohio, Alabama, and Tennessee. The works employ 60 hands, and have a capacity of 30 tons per week.

J. D. Marshbank & Son's Works.

These works manufacture steam and hot-water fittings; also, various descriptions of heavy and light castings. The annual value of their product is $30,000, and they give employment to 35 hands.

In addition to the above, there are numerous other iron industries in Harrisburg.

Bay Bros. carry on a general foundry business, with a probable annual capacity of 500 tons.

The Wilson Manufacturing Company are manufacturers of agricultural implements, and make a variety of castings.

Harrisburg Firebrick Works,

GEORGE W. BUEHLER, TREASURER.

These works were built in 1869, and have been in successful operation since that date. They manufacture firebrick for blast furnaces, steel works, and rolling-mill use, and have a capacity of 2,000,000 brick per annum, which amount could be readily increased. The clays used are from the several well-known deposits in New Jersey, and from Clearfield, Clinton, Dauphin, and Lebanon counties in Pennsylvania. All the firebrick are made of these several clays combined in various proportions as best suits the intended use.

A forty horse power engine is employed in grinding and mixing the clays. The works give employment to 30 hands.

Hydraulic Cement Pipe Works,

HENRY J. BEATTY, PROPRIETOR.

These works have been in successful operation during the past eighteen months, manufacturing cement drain-pipes, and cement ware, or artificial stone. The product is sold throughout the whole of Central Pennsylvania. The capacity of the works is 25,000 feet of drain-pipe per annum. The capital invested is $15,000, and the works give employment to 12 men.

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HARRISBURG COTTON MILL,

GEORGE CALDER, JR., PROPRIETOR.

This mill was built some 25 years ago. It has 8000 spindles and 280 looms, with a capacity of 2700 bales cotton, producing cheviots, drilling, four-shaft twills, duck, warps, yarns, etc. The number of hands employed is 260, and the monthly pay-roll amounts to $4500.

The lumber and saw-mill interests are quite large in Harrisburg and vicinity, and there are two large sash, door, and blind factories.

There are also two *flouring mills*, owned by the McCormick Estate,—the Paxton mill, with a capacity of 400 barrels per day by the new process, and the Lochiel mill, with a capacity of 100 barrels per day.

BRUSHER, MCCULLOCH & CO.

This firm have recently begun the manufacture of handles for axes, picks, etc. Capacity, 150 dozen handles per day; employs 40 men.

THE ANALYSIS OF IRON ORES CONTAINING BOTH PHOSPHORIC AND TITANIC ACIDS.

BY THOMAS M. DROWN, M.D., AND P. W. SHIMER, M.E., EASTON, PA.

THE precipitation of phosphoric with titanic acid, by boiling an iron solution which had been reduced to the ferrous condition by sulphuretted hydrogen or sulphurous acid, was first noticed by E. H. Bogardus in 1874.* Since that time, as far as we are aware, not much has been published on the relation of these two acids to each other, and to silicic acid, in the ordinary course of analysis of iron ores. The following investigation may perhaps aid in clearing up some of the obscure points in the analysis of titaniferous ores.

THE DETERMINATION OF PHOSPHORUS.

From two to five grams of the finely powdered ore are weighed into a beaker and treated with about 50 c.c. of hydrochloric acid (sp. gr. 1.12), evaporated to dryness, and heated in an air-bath for

* American Journal of Science, III, 8, p. 334.

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an hour to 110° to 120° C. To the dry mass are added 50 c.c. of hydrochloric acid (1.12), and the solution filtered off from the insoluble residue. On washing this residue with water the filtrate often runs through turbid. This can be avoided by washing with dilute nitric acid, or, better, with an acid solution of ammonium nitrate. The filtrate contains the greater part of the phosphoric acid, but the residue may contain a notable amount.

Treatment of the Residue.—Fuse the residue with sodium carbonate and extract with water. Sodium phosphate and silicate go into solution and sodium titanate remains insoluble. Filter, acidify the filtrate with nitric acid, evaporate to dryness, moisten with nitric acid, and dissolve in water. Filter from the silica, concentrate the filtrate, neutralize nearly with ammonia, and precipitate with ammonium molybdate. This is the best method of separating the phosphorus from the insoluble residue. The greater part of the phosphorus may, however, be extracted from the moist residue by washing with ammonia.

Treatment of the Filtrate.—Evaporate to a small bulk, and add enough nitric acid to drive off all the hydrochloric acid on evaporation. If the concentrated solution is clear, add ammonia until a slight permanent precipitate is formed; redissolve this in a few drops of nitric acid, and add ammonium molybdate solution.

In the ores of which we are speaking, a precipitate generally separates on evaporating to a small bulk. The addition of more nitric acid with continued heat often redissolves this; in this case, the evaporation must not be carried too far, or the precipitate will again separate. This precipitate contains phosphoric acid and titanic acid. If it is impossible to get it into solution in nitric acid, it must be filtered off and washed with ammonium nitrate solution. It is then ignited, fused with sodium carbonate, extracted with water, and the filtrate, after acidifying with nitric acid, precipitated with molybdate solution.

After the addition of the ammonium molybdate to the main solution, as mentioned above, it is heated rather hot, say from 50° to 70° C., for half an hour, with frequent vigorous stirring. The precipitate is usually allowed to stand over night, but if filtered within two hours, there will be no appreciable amount of phosphorus unprecipitated. The yellow precipitate is filtered off and washed well with a mixture of 325 c.c. of nitric acid (sp. gr. 1.2), 100 c.c. of ammonium hydrate (sp. gr. 0.96), and 100 c.c. of water. It is then dissolved upon the filter in dilute ammonia. The solution

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will probably run through turbid, and a gelatinous residue will remain in the filter. The solution is heated for some time and filtered, and this residue, which contains both phosphoric and titanic acid, is treated, together with the gelatinous residue insoluble in ammonia, with nitric acid, and the resulting solution precipitated with ammonium molybdate. By heating and stirring, the phosphoric acid can be completely precipitated in an hour, so that it will not retard the analysis materially. The solution of this yellow precipitate in ammonia is to be added to the main ammoniacal solution, and magnesia mixture added with the usual precautions. By active stirring after the addition of magnesia mixture the complete precipitation of the phosphoric acid may be effected in an hour or two.* In the analysis of an ore containing 4.74 per cent. of phosphoric acid (mostly as apatite) and 0.65 per cent. of titanic acid, the phosphoric acid was found (in duplicate analyses) as follows:

	I.	II.
Phosphoric acid in the hydrochloric acid solution,	4.370	4.330
Phosphoric acid in the residue insoluble in hydrochloric acid,	0.280	0.390
Phosphoric acid in the precipitate which separated from the solution of the yellow precipitate in ammonium hydrate,	0.016	0.027
Total,	4.666	4.747

DETERMINATION OF THE TITANIC ACID.

One to two grams of the finely powdered ore are weighed into a large platinum crucible. Potassium bisulphate† to the amount of 12 to 15 times the weight of the ore is next weighed out in another vessel. Mix the ore in the bottom of the crucible with about one-quarter of the bisulphate, and fuse until the excess of sulphuric acid is nearly all driven off. During the progress of the fusion, the lid must be lifted a very little at short intervals, in order to watch the state of the fusion. It should not be allowed to rise above two-thirds the height of the

* The action of stirring, or other agitation, in hastening precipitation, although well known, is not, I think, as often made use of in analysis as it might be.

† In order to make a successful determination of titanic acid, it is necessary to have good potassium bisulphate. This can seldom be bought in a condition fit for use. It usually contains water; sometimes an excess of sulphuric acid; it also usually contains an insoluble silicious residue. To prepare it for use, it is dissolved in water and filtered, the solution evaporated to dryness, and fused until all the water is driven off and the mass is in quiet fusion. It is sometimes necessary to drive off some sulphuric acid. It is then powdered for use. Bisulphate thus prepared will not mount excessively in the crucible, and a quiet fusion at a red heat can be obtained.

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crucible. Add now another quarter of the bisulphate, and heat again as before, until nearly all the excess of sulphuric acid is driven off. Then add the remaining half of the bisulphate, and heat until the whole mass is in quiet fusion. Too much sulphuric acid should not be driven off at this stage, or the subsequent solution in water will be retarded. The fused mass may be poured out into a large platinum dish, or it may be removed from the crucible in one lump by inserting a stout piece of platinum wire while still soft, and allowing the mass to solidify about it. A gentle heat on the outside of the crucible will quickly loosen the mass, which may now be lifted out easily. The former method is preferable, because of the thinness of the mass and its readier solubility.

When the mass has become cold, it is dissolved in plenty of cold water. This usually requires at least twelve hours. When it is evident that all has dissolved but silica and silicates,* filter into a large beaker. This insoluble residue should, after ignition, be again fused with bisulphate and tested as below for titanic acid. To the main solution we add sodium carbonate solution until a slight permanent precipitate is obtained, then 3 to 4 c.c. of sulphuric acid of 1.23 sp. gr. This redissolves the slight precipitate and makes the solution sufficiently acid. Add now sulphurous acid in excess, and dilute largely with water (1 to 1.5 liter); cover with a watch-glass, and boil about two hours, adding sulphurous acid solution and water as the evaporation goes on.

The titanic acid is precipitated, and with it phosphoric acid and oxide of iron. Filter hot (best done by means of a siphon), and wash with hot water. This precipitate of titanic acid and phosphoric acid is not finely granular like that of pure titanic acid, but is flocculent, and shows no tendency to run through even a very porous filter. It is dried, ignited, and weighed. In spite of the fact that it contains a very notable amount of iron, it is usually white after ignition. It is fused with sodium carbonate and extracted with water. Sodium titanate and oxide of iron remain insoluble, while sodium phosphate goes into solution. The residue is dissolved in sulphuric acid (sp. gr. 1.23), filtered, neutralized with sodium carbonate, 2 to 3 c.c. of sulphuric acid added, and then sulphurous acid as above. The titanic acid precipitated from this solution is free from phosphoric acid and iron.

* In ores containing lime, calcium sulphate is often found in this insoluble residue.

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If, instead of fusing the first precipitate of titanic acid with sodium carbonate, it is re-fused with potassium bisulphate, there will remain on treatment with cold water an insoluble residue containing titanic acid and phosphoric acid.

The following analytical results will illustrate the foregoing description:

	I.	II.
First precipitate of titanic acid containing phosphoric acid and iron (in duplicate), per cent.,	3.18	2.40

No. 1 was fused with sodium carbonate and treated with water as above. It consisted of—

Titanic acid,	0.65
Phosphoric acid,	1.60
Sesquioxide of iron,	.84
Loss,	.09
	3.18

No. 2 was fused with potassium bisulphate, and gave:

Residue insoluble in cold water,	1.83
Precipitate by boiling the solution,	.34
Sesquioxide of iron, by difference,	.23
	2.40

The titanic acid precipitated by boiling (.34) contained both phosphoric acid and iron.

The residue insoluble in cold water (1.83) was fused with sodium carbonate as described above; it gave:

Phosphoric acid,	.96
Titanic acid,	.42
Sesquioxide of iron, by difference,	.45
	1.83

The precipitate by boiling (.34), similarly treated, gave:

Phosphoric acid,	.05
Titanic acid,	.12
Sesquioxide of iron, by difference,	.17
	.34

The complete analysis of the original precipitate (2.40) thus shows:

Titanic acid,	.54
Phosphoric acid,	1.01
Sesquioxide of iron, by difference,	.85
	2.40

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The titanic acid is here doubtless .10 per cent. too low, owing to the many fusions and precipitations to which it was subjected.

DETERMINATION OF IRON.

If the ore contains less than one per cent. of titanic acid, no appreciable error will result from neglecting it. If it contains more than this, the iron must be determined in the filtrate from the titanic acid. The first precipitation of titanic acid contains iron. This is separated by the sodium carbonate fusion, and may be added to the main solution after separation of the titanic acid. The iron is then determined by reduction with zinc and titration with permanganate.

DETERMINATION OF SILICA AND ALUMINA.

When an iron ore containing phosphoric and titanic acids is treated for silica by the usual method (fusion with sodium carbonate, solution in dilute hydrochloric acid, evaporation to dryness, and separation of silica at 110° C., solution in hydrochloric acid and water, and filtration from the insoluble residue), the silicious residue consists of silica, titanic acid, phosphoric acid, and iron. In the case of an ore containing 3.50 per cent. of silica, this residue (which, in spite of the iron in it, is white after ignition) amounted to 6.11 per cent. The presence of phosphoric acid and iron with the silica of course renders worthless the estimation of alumina by difference.

Before speaking of the determination of the silica, we will consider how we may get the phosphoric acid and iron into the main solution where they belong. The insoluble residue (containing silica, titanic acid, phosphoric acid, and iron) is fused with sodium carbonate, and extracted with water. Sodium phosphate and silicate dissolve, and sodium titanate and ferric oxide remain behind. Acidify the filtrate with hydrochloric acid, and evaporate to dryness; take up with hydrochloric acid and water, and filter off the silica; add the filtrate to the solution to be precipitated by sodium acetate. Dissolve the residue insoluble in water (containing the sodium titanate and ferric oxide) in sulphuric acid, and separate the titanic acid from the iron by boiling, as usual. Filter from the titanic acid, and add bromine-water to the filtrate, in order to oxidize the iron, boil, and precipitate the iron with ammonia. Filter and weigh it with the precipitate of iron, alumina, and phosphoric acid, separated as basic acetate.

Some titanic acid may go into the filtrate, which is to be precipitated by sodium acetate. In this case, it will contaminate the pre-

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cipitate of iron, alumina, and phosphoric acid. It is therefore necessary, after this precipitate has been weighed, to grind it in an agate mortar, and weigh out accurately as much of it as possible, fuse with potassium bisulphate, and determine the titanic acid in it by boiling, etc. The titanic acid thus found is to be deducted from the weight of the original precipitate. There will not in all cases be titanic acid in this precipitate, but it is not safe to omit testing for it.

The silica may also be determined by fusing the residue from the second bisulphate fusion for titanic acid with sodium carbonate, and separating the silica, as usual. Or it may be determined by fusing 1 to 1.5 grams of the ore with sodium carbonate, dissolving in hydrochloric acid, and adding an excess (50 c.c.) of sulphuric acid (1.23), and evaporating until all the hydrochloric acid is driven off. This renders the silica insoluble. By now dissolving the ferric sulphate in a large excess of hydrochloric acid by aid of heat, everything goes into solution but the silica. When this point is reached, it is known by the absence of everything but transparent gelatinous silica floating in flocks in the clear solution. Calcium sulphate may contaminate the silica, if the ore contains much lime; but it does not look like gelatinous silica, and dissolves on dilution with water.

The following determinations illustrate the foregoing description:

	I.	II.
Insoluble in hydrochloric acid, .	6.11 per cent.	5.38 per cent.

Fused with sodium carbonate and extracted with water; solution contained:

I.		II.	
Silica, ...	3.31	Silica, ...	3.63
Phosphoric acid, . .	1.03	Phosphoric acid, . .	.71

Residue contained:

I.		II.	
Titanic acid, . . .	.65	Titanic acid, . . .	.65
Sesquioxide of iron, . .	1 33	Sesquioxide of iron, . .	.58

Totals.

	I.	II.
Silica, ...	3.31	3.63
Phosphoric acid, ...	1.03	.71
Titanic acid, ...	.65	.65
Sesquioxide of iron, ...	1.33	.58
	6.82	5.57

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detail the amount of *available* coal in each county and in each bed. Heretofore the data to do this have been lacking, but now, since the completion by the Geological Survey of the series of county reports, illustrated by geologically-colored county maps, it is possible to take up each county separately, and estimate in detail the approximate contents of each seam.

The general estimates, to which I have referred as lacking the elements of detail essential to accuracy, have generally been made by multiplying the total *area* covered by coal measures by an *assumed average* of the united thicknesses of the workable seams. Thus some estimates place this area at between twelve and thirteen thousand square miles, and the average coal thickness at from fifteen to thirty feet, or the amount of available coal at from 180,000,000,000 to 300,000,000,000 tons. By reference to the tables accompanying this paper it will be seen that these figures greatly exceed the total of my detailed estimates.

Calculations based on an *assumed* average thickness of coal must necessarily give untrustworthy results, because it is not possible to determine *a priori*, and in advance of detailed estimates, the average coal thickness in a field when every bed is subject to more or less radical variation in its thickness and quality.

The compiled columnar section of the coal measures accompanying this paper (scale 200 feet to 1 inch) shows sixteen important workable seams, besides several beds of minor importance, but no one of these seams is of workable thickness and quality over its entire area, and many of them—notably the thickest and best—extend into but a few of the thirty-one coal counties, while ten or twelve of these counties contain only the lowest seams of the series.

In counties containing throughout their entire area persistent seams of coal, large deductions are to be made for areas over which the coal thins out to an unprofitable thickness, or becomes locally too impure to furnish a marketable fuel.

I have not attempted to calculate the several coal areas with any great degree of accuracy; with few exceptions, the areas are expressed in acres reduced from measurements based on a unit of five square miles, hence these acreages nearly all appear as multiples of 3200 acres. The maps from which the calculations were made are drawn on a scale of two miles to one inch, and as these are necessarily only approximately correct, both in the ground plan and coloring, a finer differentiation would but lend false pretensions of accuracy to work necessarily involving errors of considerable magnitude.

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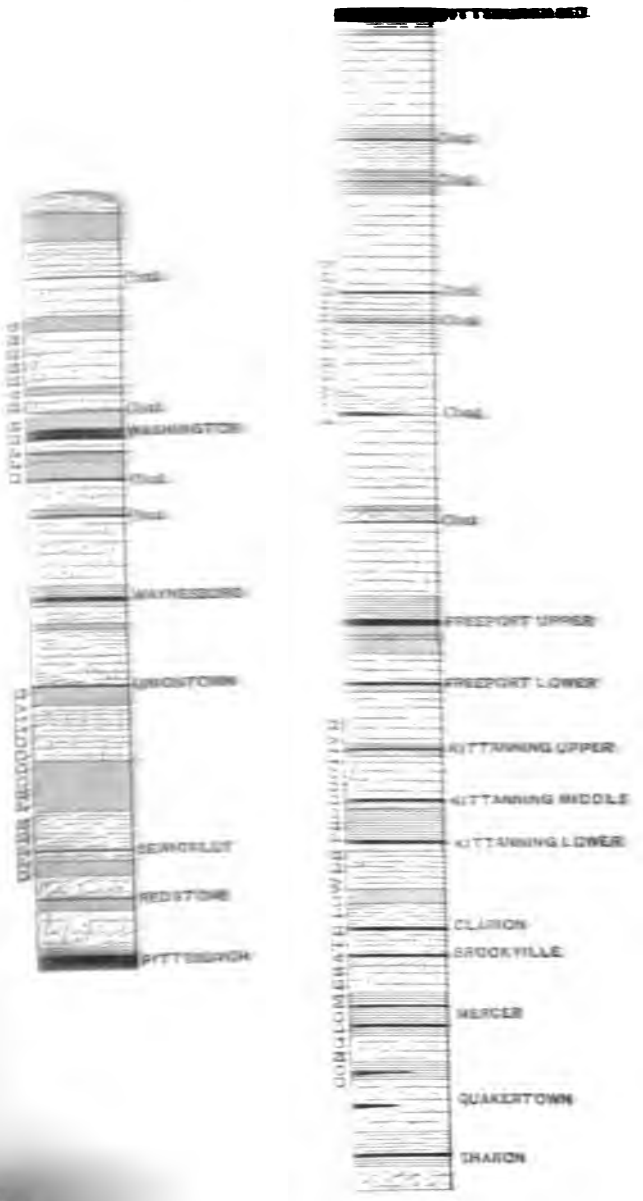
...ALS OF PENNSYLVANIA



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Seams less than two feet thick have been ignored. The areas of beds from two to three feet thick are calculated down to water-level; their areas beneath water-level have been ignored. Seams from three to five feet thick are estimated to a depth of one hundred and fifty feet beneath water-level. The areas of seams more than five feet thick are computed to a depth of four hundred feet beneath water-level when their quality and thickness are known. The areas of beds more than four feet thick, lying above water-level, but overlaid by a great thickness of superimposed measures, have been calculated so as to include a distance of from one to two miles from their outcrop lines, varying with the dip.

The maps from which the areas were computed are colored in five tints to represent the subdivisions of the carboniferous system of rocks, as follows:

Upper Barren Coal measures.
Upper Productive Coal measures.
Lower Barren Coal measures.
Lower Productive Coal measures.
Conglomerate series (with coals).

The lower edge of the Upper Productive tint limits the Pittsburgh bed; the Lower Barren tint defines the Freeport upper coal, and the Lower Productive tint the Brookville coal-bed; the areas of intermediate or higher seams were estimated from assumed intermediate outcrop lines.

After computing the total area of each persistent seam in any county, the percentage of this area over which the bed is of workable quality and thickness and its average thickness were arbitrarily assumed after a careful study of the data published in the county reports. It is evident that there is here introduced a large personal error; it is impossible to entirely eliminate such errors, but they can hardly be large enough to seriously impair the value of the conclusions. The mass of facts published in each county report thoroughly demonstrates the character and value of each coal seam, and limits this personal error between comparatively narrow bounds.

But no matter how much time and care are spent upon such work, the personal error must always be a factor of some importance. Even in the anthracite regions, which are so thoroughly developed by actual mining as well as by an immense amount of prospecting work, there seems to be some difficulty in estimating the available coal. In his report on the Philadelphia and Reading Coal and Iron Company's property, Mr. Joseph S. Harris estimates the available coal of the

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anthracite regions at 13,999.8 square miles one foot thick,—equivalent to about 15,600,000,000 tons,—and the coal area at 483 square miles. In a paper read September 1st, 1879, before the American Association for the Advancement of Science, Mr. P. W. Sheafer estimates the available tonnage at 26,361,076,000 tons, placing the coal area at 470 square miles. It is evident that the discordance between these two estimates is due to an unavoidable personal error; Mr. Sheafer estimating the average coal thickness at nearly double that assumed by Mr. Harris,—the estimates of coal areas differing very slightly.

The *coefficient of error* is probably greatest in the counties containing very small available areas,—these have been most liberally estimated; but in the counties containing large available areas the estimates are probably much less than the actual amount, as I have strenuously endeavored to underestimate rather than exaggerate the available tonnage.

The actual average coal contents per acre for each foot of bed measurement is somewhat in excess of 1650 tons, but deducting *one-eleventh* for slate, bone, and sulphur partings, I have assumed an average of 1500 tons per acre for each foot of bed measurement.

The total amount of available coal, limited as above to depth, thickness, etc., is 33,547,200,000 tons.* Assuming that 75 per cent. of this can be won in mining we have 25,160,400,000 tons as the posible product; sufficient to supply the whole world with fuel for eighty or ninety years at the present rate of consumption.

There is little doubt but that under good mining management fully 75 per cent. of the coal can be recovered. Under favorable circumstances, more than 90 per cent. should be won at mines worked on the long-wall plan or on a modification of the long-wall and panel systems.

The total available tonnage may be divided thus:

Beds over 6 feet thick, ...	10,957,200,000
Beds from 3 to 6 feet thick, . . .	19,586,800,000
Beds from 2 to 3 feet thick, . . .	3,003,200,000
Total, ...	33,547,200,000

Excluding coals less than three feet in thickness we have an available tonnage of 30,544,000,000 tons, and if 75 per cent. of this is recovered we have 22,908,000,000 tons as the possible output from seams three feet or more in thickness. Probably two-thirds of this

* The estimates do not include the Broad Top coal-field.

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amount lies favorably situated for mining, and at ordinary prices for labor can be mined and placed on the cars at an average cost not exceeding one dollar per ton; but the remaining third lies beneath water-level, or beneath a thick covering of superimposed measures, and will probably cost from one dollar and a quarter to one dollar and a half per ton at the present price of labor. This two-thirds = 15,272,000,000 tons, accessible above water-level, and contained in beds not less than three feet thick, is sufficient to maintain the present average yearly output from Pennsylvania for about eight hundred years, or to supply the whole world for fifty years.

The statistics of production show a yearly increase of about 6 per cent. from 1864 to the present time. If this ratio of increase is maintained, the yearly output will reach an enormous figure in thirty or forty years (as shown in the first column of the following table); but as West Virginia, Ohio, Indiana, and several of the Western States are rapidly developing their coal resources and taking their share of the increased demand, it does not seem probable that this percentage of increase can long continue, and I have accordingly calculated another table on a scale of decreasing percentages of increase,—shown in the second column,—estimated on a basis of 16,000,000 tons production in 1880.

Year.	Yearly Tonnage.	Yearly Tonnage.	Yearly Increase.
1880	16,000,000	16,000,000	. . . .
1890	28,640,000	28,640,000	6 per cent.
1900	51,265,600	46,396,800	5 "
1910	91,765,424	68,000,000	4 "
1920	164,270,219	91,120,000	3 "
1930	. . . .	111,166,450	2 "
1940	. . . .	122,840,000	1 "

Although the figures of the second column are much smaller than those of the first column, they still are in my opinion much in excess of any output we will ever reach in Pennsylvania. I am inclined to think that the ratio of increase will diminish more rapidly, —say 1 per cent. every five years,—that the maximum output will be reached between 1900 and 1920, and will not exceed 50,000,000

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tons per annum. At this rate more than five centuries will be required to exhaust the coal.

Seams less than three feet in thickness, unless of unusual purity, or located in the counties forming the northern edge of the coal-field, are of little importance at present; nearly all the coal now marketed coming from seams averaging three and a half feet or more. Many of the smaller and more impure coals will never be marketed, although they will answer well to supply the local demand for domestic use and small manufacturing establishments. Probably 10 per cent. of the total available coal will be used to meet this demand, but only a small percentage of this will actually be won in mining, as small mines (*country banks*), worked vicariously from year to year, are almost invariably mismanaged, and more than one-half the coal irrecoverably lost.

The possible output from beds above water-level, and more than three feet thick, has already been estimated at 15,272,000,000 tons. It will be safe to assume that one-third of this will be of sufficiently good quality to furnish good coke, an amount (5,090,666,666 tons) sufficient to smelt 2,500,000,000 tons of iron; the remaining ten thousand million tons will furnish excellent gas and steam coals.

The average workable thickness and available tonnage of each seam are shown in the following table, which is illustrated by the columnar section (page 146) drawn on a scale of two hundred feet to an inch.

Upper Barren measures:		
Washington bed, 3′–3½′, . . .	787,200,000	
		787,200,000
Upper Productive measures:		
Waynesburg bed, 3′–5′, . . .	2,126,400,000	
Uniontown bed, 2′–3′, . . .	312,000,000	
Sewickley bed, 3′, ...	432,000,000	
Redstone bed, 2′–3′, ...	326,400,000	
Pittsburgh bed, 6′–12′, . . .	10,438,800,000	
		13,635,600,000
Lower Barren measures:		
Brush Creek, Coleman, etc., beds, .	878,400,000	
		878,400,000
Lower Productive measures:		
In Westmoreland, Fayette, and Allegheny counties, ...	2,064,000,000	
Millerstown bed, 3′, ...	28,800,000	
Freeport upper bed, 3′–5′, . .	8,764,800,000	
Freeport lower bed, 2′–6′, . .	2,385,600,000	
Kittanning upper bed, 2′–4′, . .	1,596,000,000	
Kittanning middle bed, 2′–3′, . .	829,800,000	
Kittanning lower bed, 2′–6′, . .	4,225,200,000	
Clarion coals, 2′–3′, ...	696,000,000	
Brookville bed, 2′–4′, . . .	1,627,200,000	
		17,217,400,000

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Conglomerate series:		
Mercer coals, 2′–3′, ...	932,600,000	
Quakertown bed, 2′, . . .	57,600,000	
Sharon coal horizon, 2′–3′, . .	38,400,000	
		1,028,600,000
Total, ...		33,547,200,000

UPPER BARREN MEASURES.

The Upper Barren measures furnish but one workable seam, the Upper Productive measures five beds, the Lower Barren measures three or four coals attaining workable size in parts of three or four counties, the Lower Productive measures eight workable seams, and the Conglomerate series three or four seams, workable over limited areas in the northwestern counties.

This series furnishes but one seam of commercial importance, the Washington bed, which attains its best development in Washington and Fayette counties, but is not persistent as a workable seam in any other county. This series of rocks contains (see section) several other seams, but they are usually very thin and of poor quality, although one—the Waynesburg "A" bed — may prove workable over a small area in Fayette County.

UPPER PRODUCTIVE MEASURES.

Waynesburg Bed.—This is a seam of great importance in Greene and Washington counties, attaining also a good thickness in Fayette and Westmoreland, holding the fifth place among the productive coal seams. Professor Stevenson's admirable maps show its depth beneath the surface at almost every cross-road and town in Greene and Washington counties.*

Uniontown Bed.—This is locally workable in parts of Fayette and Greene counties. It is of little importance.

Sewickley Bed.—The same remarks apply equally well to this bed, and to the

Redstone Bed, which is also locally workable in Westmoreland and Allegheny counties, with an average thickness of from two to three feet.

Pittsburgh Bed.—This is the best and most valuable seam of the bituminous coal area. It ranges from six to twelve feet in thickness, and according to my estimates contains nearly one-third of the available bituminous coal in Pennsylvania. Its most extensive areas are

* See Reports K, KK, and KKK, of the Second Geological Survey of Pennsylvania.

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found in Fayette, Washington, Allegheny, Westmoreland, and Greene counties, small areas also occurring in Indiana, Somerset, and Beaver counties. The purity and quality of this coal, and the excellent character of coke made from it,—the famous Connellsville,—render it many times more valuable than any other seam.

In parts of Washington and in Greene County it lies deeply covered beneath a great thickness of overlying measures, but its depth at almost any point can be easily determined from Professor J. J. Stevenson's maps.*

LOWER BARREN MEASURES.

In Indiana, Somerset, and Butler counties this series contains several beds, attaining workable size over limited areas, and in Armstrong and Beaver counties there is also a small quantity of mineable coal in these measures. It will probably be worked principally to supply the local demand.

LOWER PRODUCTIVE MEASURES.

In Fayette and Westmoreland counties the coals of this series contain a large amount of available coal; in Allegheny County the Freeport coals will furnish a large supply, but they are always of inferior quality. The tonnage of these three counties available from the Lower Productive measures was estimated *en masse*, the data not being sufficient to warrant a finer differentiation.

Millerstown Bed.—This is locally workable in Butler County; it will be mined to meet the local demand.

Freeport Upper Coal.—This bed is workable in parts of fifteen counties. It furnishes some excellent coal, is often a superior coking coal, and in the western counties is always a strong steam and often a good gas coal. A small area of this seam in Clarion County is of a "block" character, and the coal has been used raw in a small furnace (10′ x 33′) to smelt the limestone carbonate ores. This bed ranks third among the productive seams.

Freeport Lower Coal.—A bed of great importance in Jefferson, Indiana, Clearfield, Cambria, Armstrong, Centre, and Allegheny counties, and workable in parts of Beaver, Butler, Elk, Blair, Cameron, Westmoreland, and Fayette counties. It ranks fourth among the productive seams, and will furnish a large supply of good steam, coking, and gas coals, the character varying with the locality.

Kittanning Upper Coal.—Nearly all of the cannel coal in Penn-

* Reports K and KK.

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sylvania occurs at this horizon. It is the celebrated "Darlington" bed. The seam often consists partly of cannel and partly of bituminous coal, but is most frequently a bituminous seam of fair quality, attaining workable thickness in parts of Butler, Armstrong, Somerset (bed "D"), Beaver (cannel), Indiana, Jefferson, Elk, and Lycoming counties. It holds the seventh place among the productive seams.

Kittanning Middle Coal.—This becomes locally workable in Butler, Lawrence, Jefferson, Armstrong, Elk, Cameron, and Clarion counties. It will furnish probably one-half as much coal as the Kittanning Upper bed.

Kittanning Lower Coal.—In twenty-two counties this bed attains a workable thickness and lies above water-level, favorably situated for mining. The seam lettered "B" in Clinton, Bradford, Lycoming, Tioga, and Sullivan counties has been considered its eastern equivalent.* Along the Allegheny escarpment it is an excellent coking coal, and in the western counties often a good gas coal, and always a strong steam coal. In point of production it probably ranks second only to the Pittsburgh bed; but the Freeport Upper coal may possibly equal or slightly exceed it in the amount of easily accessible coal. It averages from two to four feet in the western, and from three to six feet in the eastern counties.

Clarion Bed.—This is formed in two subdivisions in some of the western counties, its upper split being known as the "Scrub-grass" coal.† Its output will probably be applied almost exclusively to satisfy the local demand. It sometimes furnishes coal of excellent quality, but the bed is usually quite thin.

Brookville Bed.—Bed "A" of the Allegheny escarpment counties. It will be about equally productive with the Kittanning Upper seam, but often furnishes a very sulphurous fuel.

CONGLOMERATE SERIES.

Mercer Coals.—The Mercer Upper and Lower coals are workable over limited areas in Lawrence, Jefferson, McKean, Elk, Mercer, Venango, and Forest (?) counties. Excepting in McKean, where their proximity to market enhances their value, and in Mercer County, where they attain their best development, they are of little impor-

* Reports HHHH, H_5, and H_6 showing "B" = Lower Kittanning coal.

† Reports V, VV, QQ, QQQ.

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tance. In Elk and Jefferson they will yield a considerable tonnage, but in the latter county at least this will be applied almost exclusively to meet the local demand.

Quakertown Coal.—Workable over a small area in Mercer County.

Sharon Coal.—In Mercer County this is a bed of great value, but its available area will be exhausted in the near future. This horizon will furnish a small amount of coal in Crawford and Warren counties, but in the latter county it is thin and of inferior quality. Its available tonnage has been estimated on a most liberal basis.

The area actually covered by the bituminous coal measures in Pennsylvania is about 9000 square miles. The Upper Productive series extends over but a small fractional portion of this area; the Barren measures cover a considerable area, hiding beneath a thick covering large areas of the coals of the Lower Productive measures, otherwise easily accessible. The limits adopted in making these estimates necessarily compel the exclusion of many such areas in computing the available coal.

Estimates in detail for each county are given in the following tables in alphabetical order. It may appear that in many cases very small areas are assigned to persistent seams occurring over large areas. The explanation of this will be found in the impure or variable character of the bed, or its depth beneath water-level, or beneath superimposed measures over a portion of the area. The casual observer is apt to form a favorable opinion of the quality, thickness, and regularity of coal seams not warranted by the actual facts. Finding several banks working on the same bed at different localities in a county or township, at all of which the bed is of fair quality and thickness, he is naturally led to infer that the seam will be found of equal value over all the area he has examined; but he has perhaps had no opportunity of examining an equal or greater number of trial openings, at which the bed was found to be *worthless*, for these have all been abandoned, have fallen shut, and the openings are almost obliterated. Unless this fact is kept constantly in view, and due regard is given to the variable nature of most of our bituminous coals (especially the smaller seams), estimates based on bed measurements made at *working banks* will almost invariably exaggerate the true amount of available coal of marketable quality.

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Allegheny County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick
Redstone,	2′	32,000	96,000,000	100
Pittsburgh,	10′	112,000	1,680,000,000	1750
Lower Productive Coals,	6′	80,000	720,000,000	750
		Total,	2,496,000,000	2600

Armstrong County.

Barren Measures,	2½′	6,400	24,000,000	25
Freeport Upper,	4′	128,000	768,000,000	800
Freeport Lower,	3′	48,000	216,000,000	225
Kittanning Upper,	3′	64,000	288,000,000	300
Kittanning Middle,	3′	32,000	144,000,000	150
Kittanning Lower,	3′	80,000	360,000,000	375
Clarion Coal,	2½′	12,800	48,000,000	50
Brookville,	2½′	6,400	24,000,000	25
		Total,	1,872,000,000	1950

Beaver County.

Pittsburgh Bed,	8′	800	9,600,000	10
Brush Creek,	3′	16,000	72,000,000	75
Freeport Upper,	3′	35,200	158,400,000	165
Freeport Lower,	2½′	12,800	48,000,000	50
Kittanning Upper,	2′	64,000	192,000,000	200
Kittanning Lower,	2′	51,200	153,600,000	160
Clarion Coal,	2′	6,400	19,200,000	20
		Total,	652,800,000	680

Blair County.

Freeport Upper,	4′	3,200	19,200,000	20
Freeport Lower,	2′	3,200	9,600,000	10
Kittanning Lower,	3½′	4,800	25,200,000	26
Brookville,	4′	6,400	38,400,000	40
		Total,	92,400,000	96

Bradford County.

Kittanning Lower ("B"),	4′	4,480	26,900,000	28
Brookville (Bed "A"),	2′	6,400	19,200,000	20
		Total,	46,100,000	48

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Butler County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick.
Lower Barrens, ...	3′	48,000	216,000,000	225
Millerstown Bed, ...	3′	6,400	28,800,000	30
Freeport Upper, ...	4′	70,400	422,400,000	440
Freeport Lower, ...	6′	3,200	28,800,000	30
Kittanning Upper, ...	3′	83,200	374,400,000	390
Kittanning Middle, ...	3′	44,800	201,600,000	210
Kittanning Lower, ...	3′	32,000	144,000,000	150
Clarion, ...	2′	48,000	144,000,000	150
Brookville, ...	3′	32,000	144,000,000	150
		Total,	1,704,000,000	1775

Cambria County.

Freeport Upper, ...	3½′	89,600	470,400,000	490
Freeport Lower, ...	2½′	64,000	240,000,000	250
Kittanning Lower ("B"),	3½′	128.000	672,000,000	700
Brookville ("A"), ...	3′	83,200	374,400,000	390
		Total,	1,756,800,000	1830

Cameron County.

Kittanning Middle, ...	3′	3,200	14,400,000	15
Kittanning Lower, ...	3′	9,600	43,200,000	45
Clarion Coal, ...	3′	16,000	72,000,000	75
		Total,	129,600,000	135

Centre County.

Freeport Upper, ...	4′	12,800	76.800,000	80
Freeport Lower, ...	4′	32,000	192.000,000	200
Kittanning Lower, ...	4½′	51,200	345,600,000	360
Brookville Bed, ...	3′	44,800	134.400,000	210
		Total,	748 800,000	850

Clarion County.

Freeport Upper, ...	3½′	3.200	16,800,000	17½
Freeport Lower, ...	4′	3,200	19,200,000	20
Kittanning Middle, ...	2′	25,600	76.800,000	80
Kittanning Lower, ...	3′	96,000	432,000,000	450
Clarion.	2′	32,000	96,000.000	100
Brookville, ...	2½′	12,800	48,000,000	50
		Total,	688,800,000	717½

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Clearfield County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick.
Freeport Upper, ...	4′	22.666	133,600,000	139
Freeport Lower, ...	4′	64,000	384.000.000	400
Kittanning Lower, ...	4½′	89,600	604,800,000	630
Brookville, ...	3′	64,000	288,000,000	300
		Total,	1,410,400,000	1469

Clinton County.

Kittanning Lower ("B"),	3′	9,600	43,200,000	45
Brookville ("A"), ...	2′	6,400	19,200,000	20
		Total,	62,400,000	65

Crawford County.

Sharon Horizon, ...	3′	3,200	14,400,000	15

Elk County.

Freeport Upper, ...	5′	3,200	24,000,000	25
Freeport Lower, ...	5′	6,400	48,000,000	50
Kittanning Upper, ...	2½′	16,000	60,000,000	62½
Kittanning Middle, ...	2½′	28,000	105,000,000	112½
Kittanning Lower, ...	3′	48,000	216,000,000	225
Clarion, ...	2′	57,600	172,800,000	180
Mercer Coals, ...	3′	64,000	288,000,000	300
		Total,	913,800,000	955

Forest County.

Sharon and Mercer Horizons, ?	2′	1,280?	3,800,000?	4?

Fayette County.

Upper Barrens, ...	3′	25,600	115,200,000	120
Waynesburg, ...	5′	35,200	264,000,000	275
Unioutown, ...	3′	48,000	216,000,000	225
Sewickley, ...	3′	48,000	216,000,000	225
Redstone, ...	3′	25,600	115,200,000	120
Pittsburgh, ...	12′	160,000	2,880,000,000	3000
Lower Productive Beds, .	4′	128,000	768,000,000	800
		Total,	4,574,400,000	4765

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Greene County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick.
Waynesburg, ...	5′	160,000	1,200,000,000	1250
Uniontown, ...	2′	32,000	96,000,000	100
Sewickley, ...	3′	48,000	216,000,000	225
Pittsburgh, ...	8′	96,000	1,152,000,000	1200
		Total,	2,664,000,000	2775

Indiana County.

Pittsburgh Bed, ...	7½′	12,800	144,000,000	150
Barren Measures, ...	4′	32,000	192,000,000	200
Freeport Upper, ...	4′	192,000	1,152,000,000	1200
Freeport Lower, ...	2½′	64,000	240,000,000	250
Kittanning Upper, ...	2′	32,000	96,000,000	100
Kittanning Lower ("B"),	3′	64,000	288,000,000	300
Brookville, ...	2½′	19,200	72,000,000	75
		Total,	2,184,000,000	2275

Jefferson County.

Freeport Upper, ...	3′	48,000	216,000,000	225
Freeport Lower, ...	4′	160,000	960,000,000	1000
Kittanning Upper, ...	3′	19,200	86,400,000	90
Kittanning Middle, ...	3′	16,000	72,000,000	75
Kittanning Lower, ...	2′	80,000	240,000,000	250
Brookville, ...	3′	44,800	201,600,000	210
Mercer Coals, ...	3′	48,000	216,000,000	225
		Total,	1,992,000,000	2085

Lawrence County.

Kittanning Middle, ...	3′	48,000	216,000,000	225
Kittanning Lower, ...	2′	32,000	96,000,000	100
Clarion, ...	2′	12,800	38,400,000	40
Mercer Upper, ...	3′	6,400	28,800,000	30
Mercer Lower, ...	2′	6,400	19,200,000	20
		Total,	398,400,000	415

Lycoming County.

Kittanning Upper ("D"),	4′	3,200	19,200,000	20
Kittanning Lower ("B"),	3½′	6,400	33,600,000	35
		Total,	52,800,000	55

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Mercer County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick.
Kittanning Lower, ...	2½′	3,200	12,000,000	12½
Clarion, ...	3′	16,000	72,000,000	75
Mercer Upper, ...	2½′	25,600	96,000,000	100
Mercer Lower, ...	2½′	64,000	240,000,000	250
Quakertown, ...	2′	19,200	57,600,000	60
Sharon, ...	3′	3,200	14,400,000	15
		Total,	492,000,000	512½

McKean County.

Clarion, ...	3′	3,200	14,400,000	15
Mercer Coals, ...	2′	9,600	28,800,000	30
		Total,	43,200,000	45

Potter County.

Kittanning Lower ("B"),	3′	3,200	14,400,000	15
Brookville ("A"), ...	2′	3,200	9,600,000	10
		Total,	24,000,000	25

Sullivan County.

Kittanning Lower ("B"),	3′	2,560	11,520,000	12

Somerset County.

Pittsburgh, ...	8′–10′	(Platt)	42,000,000	44
Lower Barrens, ...	6′	41,600	374,400,000	390
Freeport Upper, ...	4′	51,200	307,200,000	320
Kittanning Upper ("D"),	4′	80,000	480,000,000	500
Kittanning Lower ("B"),	3½′	64,000	336,000,000	350
Brookville ("A"), ...	3′	51,000	230,400,000	240
		Total,	1,770,000,000	1844

Tioga County.

Kittanning Lower ("B"),	6′	12,800	115,200,000	120
Brookville ("A"), ...	3′	3,200	14,400,000	15
		Total,	129,600,000	135

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Venango County.

Name of Bed.	Average Coal Thickness.	Acres.	Tons.	Square Miles, 1 foot thick.
Kittanning Lower, ...	2½′	3,200	12,000,000	12½
Clarion, ...	2′	6,400	19,200,000	20
Brookville, ...	2′	3,200	9,600,000	10
Mercer Coals, ...	2½′	3,200	12,000,000	12½
		Total,	52,800,000	55

Washington County.

Washington, ...	3½′	128,000	672,000,000	700
Waynesburg, ...	3′	128,000	576,000,000	600
Pittsburgh, ...	6′	320,000	2,880,000,000	3000
		Total,	4,128,000,000	4300

Westmoreland County.

Waynesburg, ...	3′	19,200	86,400,000	90
Redstone, ...	3′	25,600	115,200,000	120
Pittsburgh, ...	8′	137,600	1,651,200,000	1720
Lower Productive Coals, .	4′	96,000	576,000,000	600
		Total,	2,428,800,000	2530

Warren County.

Sharon Horizon, ...	2′	3,200	9,600,000	10

The reports already published by the Second Geological Survey of Pennsylvania, descriptive of the bituminous coal area, now number twenty-one octavo volumes, besides two volumes and one atlas on the fossil flora of the coal measures, and a special volume on the coke industry of the Youghiogheny. Nearly all of these reports are illustrated by geologically-colored county maps on a scale of two miles to one inch. Besides this series of maps, there is another series now in preparation on a scale of six miles to one inch, which, when completed, will be published in atlas form. At some time in the near future it is my intention to construct from these maps an accurately-colored map of the bituminous coal area. I had hoped to illustrate this paper with such a map, drawn and colored to show the relative areas of the principal productive horizons, but as the

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maps of Cambria, Somerset, Clearfield, and Centre counties are not yet completed, I have thought best to wait until all of these are finished and approved by the State geologist. The estimates of areas and tonnage in these four counties probably contain larger errors than any of the remaining districts, as it is impossible, in the absence of the geologically-colored maps, to limit the productive areas with any great degree of accuracy.

The tables showing the county tonnage develop the fact that each county contains an average of but four or five accessible seams of commercial importance.

2	counties contain	9	important seams.
2	"	8	"
4	"	7	"
2	"	6	"
2	"	5	"
7	"	4	"
2	"	3	"
7	"	2	"
3	"	1	"

If the counties are tabulated according to their available tonnage we find Fayette standing at the head, followed by Washington, Greene, Allegheny, Westmoreland, Indiana, Jefferson, Armstrong, Somerset, Cambria, Butler, Clearfield, etc., but we must not lose sight of the fact that this may not be the order in which they stand in reference to their present value and importance as coal-producing areas. Mr. Joseph S. Harris, in his able report on the Philadelphia and Reading Coal and Iron Company's property, has clearly shown that the *present money value* of any coal area depends largely upon the time at which development is commenced, the time elapsing before its maximum output is reached, and the time occupied in exhausting the tract, the present money value rapidly decreasing as any one of these variables is increased.

The same principle is undoubtedly applicable to the bituminous coal areas. Those areas, so situated that their development can be economically prosecuted at present or in the near future, possess a much greater relative present value than areas not so favorably situated; thus some of the counties forming the northern rim of the bituminous coal area are, because of their proximity to the Northern markets, and their present development, of much greater present importance as coal producers than centrally located areas containing many times as much available coal.

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The amount of coal excluded from these estimates on account of poor quality, depth beneath water-level, or beneath overlying rocks is very great. As these estimates prove the existence of an amount of easily accessible coal of good quality sufficient to supply the demand for several centuries, estimates of the tonnage of these impure seams or inaccessible areas would be of no practical value to the present generation.

CHEMICAL METHODS FOR ANALYZING RAIL-STEEL.

BY MAGNUS TROILIUS, CHEMIST TO C. P. SANDBERG, LONDON, ENGLAND.

INTRODUCTION.

BY C. P. SANDBERG.

SINCE the discussion on steel rails in America has forcibly drawn attention to the value of chemical analysis, if not as a necessary stipulation, at least as a guide to control the usual mechanical tests, some doubt has been thrown upon the accuracy of the analytical results obtained by different chemists.

To any one having the least acquaintance with chemistry, it is quite clear that if exactly similar results are to be obtained from the same borings of steel, exactly the same methods must be used by the different analysts. Hence the necessity (if complications are to be avoided) of establishing what I may call standard or normal methods, to be used both by the inspectors and by the chemists at the works. Remembering that the application of chemistry to steel-rail inspection is yet in its infancy, it is of great importance to possess a perfect acquaintance with the best methods in use.

Being myself a grateful pupil of Professor Eggertz, of the School of Mines in Sweden, it occurred to me, two years ago, that I could not do better than start a laboratory of my own, and engage one of his pupils, Mr. Troilius, for the purpose of analyzing the steel borings from mechanically-tested rails, so that I might thus obtain without delay thoroughly accurate determinations.

Moreover, in order to carry on the operations in perfect accordance with the methods used at the steel works in England and Germany, where I had to control the manufacture, I deemed it desirable to allow Mr. Troilius to go through a course of training at these works; and I gladly seize this opportunity of expressing my grateful acknowledgments to several works in England and in Germany for affording every facility for such an exchange of information as was found necessary in arriving at the best analytical methods to be used.

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The value of this preliminary training has already become evident, for, after working a year in my own laboratory, we find that the results hardly ever differ from those obtained at the works; or, at any rate, they rarely differ from the results of those professional chemists who check the same borings in case of any discrepancy.

Inasmuch as this work is principally executed for America, it naturally follows that if it is checked by American chemists, it will be of interest, both for them and for the chemists on this side of the Atlantic, to know the methods of analysis followed in the two countries. With this view, I beg to introduce the following paper, which has been very carefully worked out by Mr. M. Troilius, and, therefore, deserves the attention of the members of the Institute.

I can only say of this paper, as I have said in my own on "Rail Specifications and Rail Inspection in Europe,"* that it fully explains the methods, which I have hitherto adopted, with excellent results. But, if any better methods can be suggested by American chemists, I shall only be too glad to modify my present mode of working.

It remains for me to add that Mr. Troilius will have great pleasure in answering any questions that may be addressed to him, with reference to the following methods for the application of chemistry to steel-rail inspection.

19 Great George Street, Westminster,
London, August, 1881.

CHEMICAL METHODS FOR ANALYZING RAIL-STEEL.

USEFUL APPLIANCES.

One of the most useful and necessary appliances in a steel laboratory is the hot-plate. An iron plate, 12″ x 18″ x ⅝″ thick, heated from below by a good Bunsen burner, will answer very well. Or, if more convenient, the plate may be combined with a coke fire and a muffle-furnace, the coke fire thus heating both the plate and the muffle-furnace. In any case the plate should be heated in such a manner as to have a boiling temperature at only one part, from which part the heat should gradually decrease towards the edges. Thus arranged, the plate forms a very satisfactory substitute for water-baths, drying-boxes, etc., as will be seen in the following description of the methods. There is no risk of destroying beakers, etc., after sufficient experience in working the plate has been acquired.

A plate of this kind has been in use in the Royal School of Mines

* Transactions, vol., ix, p. 193.

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in London, for about fifteen years, but, as far as I am informed, it was Mr. Snelus who first employed a plate in this way at Dowlais, and it has since become universally used in English and Welsh laboratories. I should also mention that it has been successfully introduced in the Stockholm School of Mines, in accordance with my suggestion last year in the *Jernkontorets Annaler*. In German steel laboratories the water-bath and other more "scientific" appliances are more generally in use than in England and Wales; in fact, I have not so far seen the plate used in any of the German steel works which I have visited. It is necessary to have the plate placed under a good draught, so as to remove all the noxious fumes which are evolved during the operations conducted on the plate.

As regards other useful appliances, belonging to a well-fitted steel laboratory, they are all more or less common, or are only occasionally used, and do not deserve as much attention as the above-named plate. Fluted funnels, however, are worthy of being mentioned as being somewhat quicker to work with than ordinary plain ones. I have not found them in use on the Continent as frequently as in the United Kingdom, but they are now beginning to be somewhat more appreciated, even in Continental countries.

CARBON DETERMINATION.

Eggertz's color-test is a very accurate method for determining carbon in rail-steel, provided the operator has sufficient experience and takes all the necessary precautions. At the same time this method has the great advantage of being very rapid. It is now nearly twenty years since this method was described in Sweden and Germany by Professor Eggertz, and very shortly afterwards Mr. C. P. Sandberg published an English translation of the method in the *Chemical News*.* In Great Britain the color-test is now very largely used, every blow in the Bessemer converter being thus tested for carbon, and in the hands of skilled manipulators it gives great satisfaction. In German steel-laboratories the color-test is not so much used as in Great Britain, and costly arrangements are often employed for carrying out determinations of carbon by the combustion process on a large scale. For the daily control of rail-steel, however, this is rather an impracticable arrangement, when results, accurate within 0.01 per cent., can so rapidly be obtained by the color-test.

Experience soon taught the manipulators at steel works to modify the method in many respects, so as to attain greater rapidity, thus

* Chemical News, vol. vii., p. 254.

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deviating from the directions given by Professor Eggertz in 1862. There has, however, been some uncertainty as to many of the details, and as some rather serious discrepancies have occasionally occurred, especially in analyzing the harder classes of steels, there have not been wanting people who denounce the whole method. It is, therefore, with great pleasure that I am able to accompany this paper with a translation of Professor Eggertz's recent article on the subject. As the contents of this article, or, at least, the more important points, were kindly communicated to me some weeks before it was published in Sweden, I have had ample opportunity of applying the experience thus gained, and have found it thoroughly corroborated by my own results.

The most important facts in Professor Eggertz's paper are contained in the rules given for (1) quantity of acid required for each 0.1 gram of steels of different percentages of carbon, and (2) minimum addition of water required for each 0.1 gram of steels dissolved in nitric acid, to remove the iron color.

Referring to the complete* translation for further information, I will now explain how I carry out my determinations of carbon in rail-steel by means of the color-test. My mode of manipulation is the same as that used at most English and Welsh steel works, with the modifications of the two above-mentioned new rules of Professor Eggertz.

I use 0.2 gram of the steel for testing, and along with every set of samples 0.2 gram of standard steel is dissolved. This is indispensable with the mode of procedure I adopt, no precautions being taken to exclude the sunlight, etc. The solution is effected in test-tubes, 6 inches long and about $\frac{5}{8}$-inch internal diameter. The dimensions of the test-tubes are not a matter of great importance, but they should not be too narrow.

The nitric acid I always allow to flow into the tubes from a graduated burette, this being by far the best way of adding the acid. The tubes are then put into a beaker 4 to 5 inches high, half filled with water. The beaker may be advantageously covered with a perforated tin plate, and the tubes put through the holes and thus steadied. Heat is then applied, and boiling is continued until the steels are dissolved. This seldom requires more than half an hour, and is greatly promoted by the jumping of the tubes in the boiling water. When

* The accompanying translation contains an addition made after publishing the article in Sweden, and is thus believed to be more complete than any translation which has already appeared in print. See Appendix.

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the solution is completed, the tubes are put into cold water, and the determination of carbon is thereupon carried out by means of the carbon-tubes. The carbon-tubes are generally bought in sets of three tubes, one of which is graduated, and the other two not. The tubes in each set are selected carefully, so as to be of the greatest possible uniformity as to dimensions and quality of glass. Their capacity is 20 c.c.

In my ordinary work I put the standard-steel solution into one of the ungraduated tubes, measuring off by aid of the graduated tube, and in very particular analyses I use standard-steel solutions of different colors in both the ungraduated tubes. This helps the eye to catch faint differences in tint. The solutions for testing are put into the graduated tube.

The differences in the results, which are sometimes obtained when analyzing the harder classes of steel by the color-test, are not observed as far as rails are concerned, and I find no difficulty in obtaining accurate results in this case. In fact, as far as my experience goes, the carbon in rails is that element which can be most easily accurately determined, and this by the simple color-test. But even for harder steels a very much greater certainty is now secured by the method described in Professor Eggertz's latest publication.

It is always desirable, if not necessary, that the standard steel should have a percentage of carbon not differing too widely from the average percentage of carbon in the steels for testing; especially when dealing with *very* soft steels one finds the necessity of having a low standard.

In working this method for carbon estimation, when the carbon ranges from 0.10 to 0.80 per cent., I have obtained accurate determinations with great rapidity; and this, indeed, is the great value of the method, which is best seen by its application for ascertaining the carbon in every blow, even at the largest steel works in England, where hundreds of charges are made per day. Ordinarily, a boy is trained to do this work, under superintendence of the chief chemist, and consequently the cost of execution is but very small.

The plan of dissolving rapidly and then cooling the tubes, as just described, was originally employed by Mr. Snelus at Dowlais.

PHOSPHORUS DETERMINATION.

The greater number of steel works which I have visited use Eggertz's molybdic method for determination of phosphorus in steel. Except in Sweden, however, it is only at one large works in Ger-

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many that I have seen this method carried out in the way originally described by Professor Eggertz; and at that works superior appliances, enabled the manipulators to obtain pretty quick, and certainly very accurate, results, even when using weighed filters, and working upon the small prescribed quantity of 1 gram. At other German works it was the practice to redissolve the phospho-molybdate obtained, and to finish the analysis by the magnesia method. But at all the English and Welsh works with which I am acquainted the phosphorus is estimated by weighing the phospho-molybdate itself. Several grams of the steel are always used, and the precipitate is generally brushed off from the filter. Only at one Welsh works have I seen it gently burnt, so as merely to incinerate the filter.

The former of the two last-named modes of manipulation is the one I use. Like so many other useful modifications in the chemistry of iron and steel, this plan was originally introduced at Dowlais by Mr. Snelus. In the following pages I will describe the process, and at the same time refer briefly to the Welsh "burning" method and to the magnesia method, etc.

The Brushing Method.—The solution of the steel for the determination of phosphorus is an easy operation. Not less than 5 grams of steel are dissolved in a mixture of equal volumes of strong nitric and hydrochloric acids. (I use for this purpose nitric acid 1.42, and hydrochloric acid 1.195 sp. gr.) No loss, through escape of phosphorus, in combination with hydrogen, is hereby incurred. The solution is evaporated to dryness, and heated until all dark fumes have ceased to escape. A beaker or a porcelain dish may be used, according to circumstances, and evaporations, etc., are performed on the hot plate. By the evaporation to dryness the complete solution of the steel is secured, all organic matter is destroyed, and the silica can be separated, which is advisable if it is present in any noticeable quantity.

The dry mass is then dissolved in strong hydrochloric acid, the excess of acid removed by evaporation, hot water added, and the silica filtered off. (If little, or no silica is present, it is of course unnecessary to filter it off, and the precipitation of phosphorus may then at once be proceeded with.) The filtrate is evaporated down to a small bulk, so that it is only just fluid; it is allowed to cool, and then about 4 c.c. of the strong nitric acid are added. A little rinsing-water is introduced, so as to make the bulk about 20 c.c. The beaker is strongly shaken in the right hand, while from a pipette, which

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is held in the left hand, 20 c.c. of the solution of molybdate of ammonia are allowed to run into the beaker in a thin stream.

The solution of molybdate is prepared by dissolving 100 grams of molybdate of ammonia in 1000 c.c. of water and 100 c.c. of ammonia, 0.88 sp. gr. It is of no advantage to use less strong solutions of molybdate than this, as one has then to employ a larger quantity of the same, and thus obtain a greater bulk, the work being thereby retarded.

After pouring in the solution of the molybdate, a few drops of ammonia (0.88) are added, and the beaker is shaken until the precipitate of iron has disappeared. The phospho-molybdate is then completely down, and you have only to leave the beaker on the less hot part of the plate at least for one hour; allowing it during that time to settle, and shaking it up again repeatedly. After the last shaking the precipitate must separate distinctly, and leave a perfectly clear, supernatant solution. There is no danger of getting molybdic acid down, even if you were to boil for a moment or to use a large excess of molybdate, provided that there is a sufficiently large quantity of nitric acid present. But, if there is arsenic in the steel, this will come down along with the phosphorus and cause too high results. The use of the ammoniacal solution of molybdate of ammonia causes a considerable elevation of temperature; hence, as will be shown below, the precipitation of arsenic.

After settling, pour the liquid on to a good Swedish 4-inch filter; wash the filter with cold water, containing 1 per cent. of nitric acid, until it is quite white; wash the precipitate in the beaker once by decanting with ordinary water, moderately hot; and, finally, wash the precipitate down on the filter, and collect it at the centre, with as few washings as possible with ordinary water, moderately hot. The filter should be quite white before the precipitate is washed on to it.

If the washing is conducted in this way no loss will be incurred in dissolving, neither will the fluid run through turbid. The solubility of the phospho-molybdate precipitate, at 16° C., is given by Professor Eggertz as follows:

In pure water, ...	1 part in 10,000
In water, with 1 per cent. of nitric acid, . .	1 " 6,600
In hydrochloric acid, 1.12, ...	1 " 550
In nitric acid, 1.2, ...	1 " 190

If to the solvent be added a solution of molybdate of ammonia, equal to about half of its volume, the solvent action seems to be considerably lessened.

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After washing, unfold the filter containing the precipitate upon another filter, and put it on the edge of the plate to dry. The unfolded filter should be covered with a large watch-glass, so as to prevent dust from getting into it. As to the temperature for drying, this is by no means so essential a point as is often supposed, and the precipitate may be dried for hours at a temperature between 100° and 140° C. without changing its percentage of phosphorus in any noteworthy degree, as stated by Professor Eggertz, whose results in this respect are compiled in the following table:

Temperature.	Loss per cent. of Weight of Precipitate.
95°—100° C.	0.40
100°—120° "	0.20
120°—140° "	0.05
95°—140° "	0.65

The total loss in weight is thus only 0.65 per cent. when drying at 140° C., and this has no practical influence, considering the small amount of phosphorus in the precipitate and the large quantity of steel operated upon. The precipitate also retains its yellow color at the temperature of melting lead (325° C.), but gets black at the temperature of melting zinc (400° C.).

When dry, the precipitate is shaken down into a weighed platinum, or porcelain dish, the brush not being applied until nothing more can be loosened from the filter by mere shaking. It is a convenient practice to hold the filter in the left hand, and to knock gently on this hand with the other.

Having thus given the outlines of my mode of using the molybdic method, I would add the following precautions, which are necessary for attaining accurate results:

1st. Removing excess of hydrochloric acid from the solution by evaporation.

2d. Adding the solution of molybdate in a very thin stream, shaking well.

3d. Great care in the washing and brushing off.

As for the weighing it is advisable to dry in the vessel repeatedly, and weigh two or three times before finally deciding the weight.

In *Eggertz's original method* there is used for the determination of phosphorus in steel only 1 gram. The solution of the molybdate is prepared from 100 grams of pure molybdic acid to 422 c.c. ammonia (0.95 sp. gr.), and 1250 c.c. nitric acid (1.2 sp. gr.). By using such a small quantity of steel one advantage is gained, viz., that no

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evaporation after separation of the silica is required, the bulk being very small if the washing has been carefully performed. But of course brushing cannot be applied when such a small quantity of steel is taken; weighed filters must then be used.

As to the precipitation in this case you may manage to have the iron solution of 15 to 20 c.c. volume, and add to the same at least half its volume of the above-mentioned solution of molybdate. The solution is well stirred and left at a temperature of 40° C. for one to three hours, after which the precipitate is collected on the weighed filter, dried, and weighed.

In Sweden it is of great importance to keep the temperature not above 40° C., as some of the very purest Swedish irons and steels contain arsenic, which will come down as a yellow precipitate similar to the phospho-molybdate. At 70° C. this arsenio-molybdate (containing 4.11 per cent. of arsenic) comes down pretty quickly, and on boiling it precipitates at once. It is easy to understand how important it must be to avoid estimating the arsenic as phosphorus in, for instance, a Dannemora "Walloon" iron, where the phosphorus may be only 0.01 per cent. or less. If the right temperature be neglected the phosphorus would, perhaps, appear to be 0.02 per cent.; but this would still be serious in such pure material. In fact it is to be feared that many mistakes on the part of consumers of Swedish steels are committed through overlooking the presence of arsenic.

It falls beyond the limits of this paper to describe Professor Eggertz's method for separating and determining the arsenic in steel, and I have only to mention that I have not been troubled with arsenic in any of the rail-steels with which I have had to do.

The Burning Method.—As to the method of burning the precipitate above referred to, I may say that I saw it practiced two years ago at a large works in South Wales, but not until lately have I had time to try it myself. At the works in question it was the practice to put the wet filter containing the precipitate in a platinum crucible, and to place this in the forepart of a hot muffle-furnace, so as to incinerate the filter. A certain correction, as I was told, was made for the expelled ammonia, before taking down the result. However, I have found, hitherto, that by adding the filter to the precipitate after determination by the brushing method, in the usual way, and putting it all into a weighed porcelain crucible, then carefully charring the filter and burning it over a gentle flame from a Bunsen burner, no very different results are obtained; indeed in

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most cases I have found the weight, after burning, only so much higher than after brushing, as would correspond with the weight of the filter-ash, and in no case have I found it less than after brushing. It appears that 140° C. is the highest temperature that can be used when only drying of the precipitate is intended, for at higher temperatures the filter-paper begins to change. But as far as the above-named experiments show, it is quite feasible to incinerate the filter without practically altering the composition of the precipitate. A continued series of such experiments will give a list, the average of which will show the accuracy obtainable by the burning method.

Magnesia Methods.—In some laboratories it is usual to redissolve the phospho-molybdate obtained, and then to precipitate with magnesia-mixture. This is a rather slow and wasteful way of procedure, and the direct (Riley's) method seems then preferable.

In the direct method one may use at least 10 grams of steel. The hydrochloric acid solution is reduced by means of sulphite of soda, the excess of sulphurous acid is removed by boiling, the solution is then neutralized with ammonia, and bromine added so as to oxidize about 0.3 to 0.4 gram of iron. The sesquioxide of iron is precipitated by means of acetate of soda, and the whole of the phosphorus in the steel is supposed to be precipitated along with it.

The precipitate is filtered off and dissolved in hydrochloric acid, about 13 grams of citric acid are added, and the solution is neutralized with ammonia; 20 to 30 drops of magnesia-mixture are then added, and some ammonia. The whole should be left for two days, and be stirred up now and then during that time, before it is finally filtered; the precipitate is washed with ammoniacal water, ignited and weighed.

It is difficult to see wherein the advantage of using this method lies, as compared with the direct weighing of the phospho-molybdate. The ignited pyro-phosphate of magnesia contains 27.95 per cent. of phosphorus, and an error in weighing must have, therefore, a serious influence on the result, unless a very large quantity of the steel is used. But altogether, the magnesia method requires much more time, skill, and labor, than the molybdic method. To this should be added the statement by Professor Eggertz, that it is exceedingly difficult to obtain the reagents used in the magnesia method free from phosphorus, whereas in the molybdic-acid method it is only the nitric acid which may contain phosphorus. Too high results are, therefore, frequently obtained by the magnesia method.

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In conclusion, I may say that the above-described brushing method, which I use daily, has given very accurate results, as the same borings have been checked by some of the leading chemists of the day. As to the time required, if several analyses are performed at the same time, and suitable arrangements made, two or three or even more results may be obtained in a day.

SILICON DETERMINATION.

For determining silicon in rail-steel I use the aqua-regia and the sulphuric-acid methods. The former has been sufficiently described in connection with the phosphorus determination, and I will here, therefore, only mention the principal details of the latter.

For each gram of steel I use 14 c.c. of a mixture of sulphuric acid and water, in the proportion of 1 of sulphuric acid to 6 of water. If I wish to estimate the silicon only, no oxidizing of the solution is necessary, and I have only to boil (with exclusion of the air as far as possible) until all is dissolved, and then completely evaporate the water so as to render the silica insoluble. The white salt is then taken up with hot water and a few drops of strong hydrochloric acid, and the silica filtered off and washed with hot water containing 5 per cent. of nitric acid.

If manganese is to be estimated in the filtrate obtained, the solution should be boiled with a few cubic centimeters of nitric acid for about one-quarter of an hour before evaporating down. After dissolving the salt in water and hydrochloric acid, boiling should be continued for another quarter of an hour before filtering off the silica, so as to insure the manganese being converted to manganous oxide. The silica must in this case be washed, first with ordinary cold water, and then with the nitric-acid water, which should flow into a separate beaker, and not into the first filtrate, where it might produce a higher state of oxidation of the manganese.

I find that the aqua-regia and the sulphuric-acid methods yield results which are quite uniform and concordant. The sulphuric acid method can be quite as rapidly used as the aqua-regia method by means of the hot plate. Two years ago I worked this method in a steel laboratory in Wales, and the chemists at the place took such a liking to it on account of the absence of the disagreeable fumes, which are evolved in the aqua-regia method, that they started working it for the daily determination of silicon in their pigs. At the present time they use the sulphuric-acid method exclusively, and are by practice enabled to work it quite as rapidly as the aqua-

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regia method. Besides being a neater method, the sulphuric-acid process effects no inconsiderable economy in daily practice, where otherwise large quantities of aqua regia must be consumed.

When using acid water, as in the sulphuric-acid method, or strong hydrochloric acid, as in the aqua-regia method, for washing the silica, I make no deduction for filter-ash. The best Swedish filter-paper does not leave any practically estimable quantity of ash when treated in that way. Otherwise a deduction is made according to Eggertz's formula:

$$\text{Ash, grams} = 0.0001\ D^2,$$

D being the diameter of the filter in inches.

MANGANESE DETERMINATION.

For determining manganese in rail-steel I use the acetate of ammonia and bromine process, with *final addition of ammonia*, as usual in English and Welsh steel laboratories. In Germany, the method with acetate of soda and bromine or chlorine, and *no final addition of a strong base*, is used, and in Sweden the acetate of soda and bromine method in accordance with Professor Eggertz's directions. In describing my mode of operating, I will also try to point out the great differences between the method with *ammoniacal salts and bromine and ammonia combined*, and the methods with *fixed alkaline salts;* and to show what are the precautions to be taken in each case to attain accuracy.

Bromine and Ammonia Process.—3 grams of steel are dissolved in a flask of 1 liter capacity by aid of aqua-regia; the solution is boiled down and finally dried. The mass is then dissolved in hydrochloric acid* by boiling; water is added to about 750 c.c. volume, and the solution neutralized with ammonia or carbonate of ammonia. If too much ammonia is added, care must be taken immediately to add some hydrochloric acid and to boil for a short time, so as to prevent manganese being precipitated. When neutralization is completed, add 20 to 30 c.c. of strongly concentrated, thick acetate of ammonia, and boil until you see the precipitate settle clear after lifting the flask off from the lamp. If the supernatant liquid will not become clear, add cautiously a few drops of strong ammonia (0.88), shake the flask and boil for a moment again. In this way you are certain to obtain a clear supernatant liquid, but you must be very careful not to add too much ammonia, as the manga-

* The silica may in this case be filtered off and estimated. If this is not required, the steel is simply dissolved in dilute hydrochloric acid, and the solution oxidized by means of nitric acid, and boiled before neutralizing.

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nese may then be partly precipitated as hydrated oxide. After settling, the clear liquid is passed through a filter of 10 inches diameter into a large flask, and finally the precipitate of basic acetate of oxide of iron is poured on to the filter and the remainder of the fluid allowed to filter well off. When no more drops seem to come from the funnel, the basic acetate is washed down into the first flask by means of boiling water, and hydrochloric acid is added. The flask is well shaken and heated to boiling in order to insure the remainder of the manganese being present only as manganous oxide. Neutralization and precipitation are then repeated as before, and the filtrate added to the first one obtained. For rail-steel I find two precipitations like these quite sufficient, the manganese in such steels rarely exceeding 1 per cent. But for spiegeleisen, ferro-manganese, etc., it is certainly desirable to redissolve twice, as the more manganese there is in the substance, the more of it will be retained in the iron precipitate. Anyhow, it should be borne in mind that a good boiling is necessary after every re-solution, in order to convert the manganese to manganous oxide.

The collected filtrates, contained in the large flask, are then allowed to cool (this takes only a short time, the first filtrate cooling the second and so on), about 4 c.c. of bromine are added and the flask well shaken, so that the fluid may be well saturated with bromine. It is safest always to add so much bromine as to have quite a reddish color in the solution. Ammonia (0.88) is then added in excess and the flask well shaken. At first the solution generally becomes quite colorless, but after continued shaking the brown color begins to be more and more evident, and soon the oxide of manganese separates in lumps. It is then boiled for a few minutes, the precipitate allowed to settle and then filtered off, washed with hot water, dried, ignited, and weighed.*

It is necessary to have the solution quite cold, and a large excess of bromine present, when precipitating the manganese in this way. If the solution be hot, a violent evolution of nitrogen gas will take place, and the manganese remains in the solution. Insufficient bromine also causes only a partial precipitation. One may write the reactions in this process as follows:

I. *Insufficient bromine:*

$$2[MnO_2(C_2H_3O)_2] + 5Br + 8NH_3 + (x+2)H_2O = (MnO_2 + xH_2O) + MnO_2(C_2H_3O)_2 + 5NH_4Br + 2[NH_4O(C_2H_3O)] + N.$$

* The precipitate is always to be tested for iron, unless the iron has been previously removed, which is generally the case.

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II. *Sufficient bromine:*

$$MnO_2(C_2H_3O)_2 + 5Br + 8NH_3 + (x+2)H_2O = (MnO_2 + xH_2O) + 5NH_4Br + 2[NH_4O(C_2H_3O)] + N.$$

The advantages of the method just described consist chiefly in the rapidity with which the precipitation, filtering, and washing of the manganese precipitate take place. The washing is very quickly finished by aid of hot water, no fixed alkaline salts being present. The ammoniacal salts do not prevent the precipitation of manganese by bromine and ammonia *combined*, and this was never disputed by any of the chemical authorities on the Continent, although it is so stated in a paper on the estimation of manganese in the *Journal of the Iron and Steel Institute* for 1877. Fresenius, Eggertz, and others assert that the manganese cannot be precipitated in the solution, after separating the iron, by bromine *alone*, if ammoniacal salts are present, and this is easily ascertained by experiment. The following description of Professor Eggertz's method will, I trust, show the differences in the two methods clearly enough.

Eggertz's Method.—Professor Eggertz, and, following in his footsteps, the chemists of Swedish steel works, use 3 grams of the steel for testing. The solution, the evaporation, and the processes belonging to the precipitation of the iron, offer nothing new to be mentioned here; it is only to be said that the bulk, in which neutralization is effected, is prescribed to be not less than 500 c.c. Carbonate of soda is used for neutralizing, and a little hydrochloric acid is always added at the end of the process. 60 c.c. of a strongly concentrated solution of acetate of soda are then added and boiling is continued for five minutes. Filtering and redissolving are effected as usual.

The solution containing the manganese is evaporated down to 400 to 500 c.c., and heated to 50° C., a few drops of bromine are added and the solution is stirred. The manganese then precipitates as hydrated dioxide. It is allowed to settle on a water-bath, filtered off, washed with cold water containing 1 per cent. of hydrochloric acid, ignited and weighed as tetra-oxide. Or it may be collected on a weighed filter, dried at 100° C., and weighed as hydrated dioxide ($3MnO_2 + H_2O$), containing 59.14 per cent. of manganese.

If ammoniacal salts are present, the precipitation of the manganese will be partly or wholly prevented. It is necessary to employ a large excess of acetate of soda, otherwise the manganese will be precipitated incompletely. This is best understood by the following equations:

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I. *Insufficient acetate of soda:*

$$2[MnO_2(C_2H_3O)_2] + 2Br + (x+2)H_2O = (MnO_2 + xH_2O) + MnBr_2 + 4[HO(C_2H_3O)].$$

II. *Sufficient acetate of soda:*

$$MnO_2(C_2H_3O)_2 + 2Br + 2[NaO(C_2H_3O)] + (x+2)H_2O = (MnO_2 + xH_2O) + 2NaBr + 4[HO(C_2H_3O)].$$

By comparing these equations with those of the bromine and ammonia process, I think a pretty clear view may be had of the different conditions of the two methods, without further comment.

After what has just been shown, there is no disguising the fact that the bromine and ammonia process is more rapid and convenient than the process with fixed alkaline salts; but it should be here pointed out that a great mistake is often committed in saying that it is impossible to free the precipitate from alkali by washing. Professor Eggertz has stated that by means of cold water containing one per cent. of hydrochloric acid the precipitate may be easily freed from alkali. In Germany, where the fixed alkali method is used, this mode of washing is not so frequently known as might be supposed, and at one works I was told that experience went to show that by using chlorine instead of bromine the washing of the precipitate with ordinary hot water could be more easily effected.

When chlorine is used for precipitating the manganese, no ammoniacal salts must be present, otherwise the explosive compound Cl_3N may be formed. On the other hand, in the case of bromine and ammonia, no explosion need be feared.

The different methods, of which the outlines have now been given, yield quite concordant results when carried out by experienced hands, and for rail-steel there is certainly no preference to be given to any of them so far as accuracy goes. According to my own working, the results should not vary more than 0.05 per cent., and the time required for an estimation one day; of course several assays can be made at the same time. As to rapidity, the bromine and ammonia process will no doubt prove the best, for reasons stated above.

There are many volumetric methods for determining manganese, but as far as I have seen, none is more rapid than the gravimetric method with bromine and ammonia. A new volumetric method has been recently devised in the Stockholm School of Mines, and will shortly be published.

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SULPHUR DETERMINATION.

I dissolve 5 grams of steel in aqua regia and separate the silica in the usual way. In the boiling solution the sulphur is precipitated by means of 2 c.c. of a concentrated solution of chloride of barium. Boiling is continued for a short time, and the solution is then left to stand during one night.

The sulphate of baryta, before being taken upon the filter, is decanted repeatedly with hot water. Some drops of hydrochloric acid must be added to prevent oxide of iron from being precipitated. By washing carefully in this way accurate results are secured, always provided that the reagents are pure. The purity of the reagents is, indeed, the difficulty in this method, as it is almost exceptional to find the acids bought as "special" free from sulphur. The sulphur must be estimated in the reagents and the necessary deductions made.

There are chemists, however, particularly in Germany, who assert that even with pure reagents you will get too high results by the aqua-regia method. They therefore use the bromine method, leading the gases from the steel dissolving in dilute hydrochloric acid through a solution of bromine in hydrochloric acid. The sulphuretted hydrogen is thus oxidized and can be precipitated in the usual way, by means of chloride of barium.

As far, however, as I have been able to see, the bromine method gives too low results. I have had to determine the sulphur in steel with the aqua-regia method against chemists using the bromine method, and on some occasions I have found 0.08 per cent., while the others have found only half of this, 0.04 per cent. By means of Eggertz's silver-plate, however, I easily ascertained that 0.04 per cent. was much too low. The experiment was carried out by hanging a clean, small silver-plate over the gases evolved from 0.1 gram of steel, dissolving in 1.3 c.c. of sulphuric acid of 1.23 sp. gr. The plate then got a decidedly more bluish than brownish color, whereas if the percentage of sulphur had been only 0.04 per cent. the color would have been simply brown and not blue at all. This plate method was worked out by Professor Eggertz, and has been for many years in use at all blast furnaces in Sweden for the daily testing of every cast of pig iron. The plate method will yield very good results for percentages of sulphur between 0 and 0.04 per cent., and this is quite sufficient for Swedish irons. But for sulphur over 0.04 per cent., the method is less accurate, except in extremely well-trained hands, and one can only make a rough estimation, as a

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rule. The relations of the colors of the plate to the percentage of sulphur is shown by the following table:

No color,	0.00 per cent.
Slightly yellowish,	0.01 "
Yellow,	0.02 "
Yellow-brown,	0.03 "
Brown,	0.04 "
Blue,	0.20 "

Between brown and blue there are numerous variations in color. A certain red tint signifies 0.10 per cent., but this can only be learnt by practice.

APPENDIX.

THE COLOR-TEST FOR CARBON IN IRON AND STEEL.

BY V. EGGERTZ.

(Translated from the Swedish by M. Trollius.)

The first description of this method appeared in the *Jernkontorets Annaler*, for 1862, page 54, and in the *Berg und Hüttenmännische Zeitung*, 1863, page 373. Subsequently, several additions were made to this description in the *Jernkontorets Annaler*, 1874, page 176, and in the *Berg und Hüttenmännische Zeitung*, 1875, page 440. At that time I considered that it would be practically sufficient to determine the carbon in tenths of a per cent., but I now find that even hundredths of a per cent. are required.

For commercial purposes, however, iron and steel is generally stamped with only whole or half tenths of a per cent. of carbon, it being chiefly for the softer irons and steels with carbon between 0.10 and 0.25 per cent., that the greater accuracy in determining the carbon is required.

Pure hydrate of oxide of iron, containing 0.1 gram of iron, and free from chlorine, will give a yellow-greenish solution when dissolved in 2.5 c.c. of nitric acid, specific gravity 1.2. The solution will lighten somewhat on addition of 1.5 c.c. of nitric acid, but not so much as when water is added instead of nitric acid. When hot, the solution has a much darker color than when cold. By adding 4 c.c. of water in either of these cases so as to make the bulk up to 8 c.c., the iron color will be totally got rid of. Hence the rule for color-tests for carbon, that the solution of iron must be diluted with a volume of water at least equal to the volume of nitric acid used for dissolving the iron, and that the volume of the solution must not be smaller than 8 c.c.,* when the color is to be observed.

* For each 0.1 gram of iron.—M. T.

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The nitric acid as well as the water must be entirely free from chlorine or hydrochloric acid, which would give a yellowish color* to the solution, even if present in only very small quantities. The quantity of nitric acid should correspond to a certain extent to the amount of carbon supposed to be present in the iron. For iron containing carbon 0.25 per cent., 2.5 c.c. are thus used for each 0.1 gram, for 0.3 per cent. 3 c.c., for 0.5 per cent. 3.5 c.c., and, finally, for 0.8 per cent. 4 c.c. For steels with more carbon 5 c.c. should be used. The last-named quantity is also to be used for white pig irons, of which, however, 0.05 gram only is carefully weighed out for each test.

When the amount of carbon is quite unknown 2.5 c.c. of nitric acid are added to start with, and then more until it is indicated by either the color or by the quantity of separated carbon-substance that no more acid is wanted. A little more acid than the quantity just mentioned does no harm, if only an equal volume of water is afterwards added. Thus for white pig iron 7 c.c. may well be taken so as to prevent a too quick precipitation of organic matters after diluting. With too little acid a too dark solution will be obtained. Thus, if 0.1 gram of steel containing 0.8 per cent. of carbon is dissolved in 2.5 c.c. of nitric acid only, instead of 4 c.c., the color of the solution will, after dilution, represent a percentage of carbon equal to about 0.9 per cent.

The iron for testing is to be finely divided either by filing,† by aid of a good clean file, or by means of a boring machine (which is preferable), or by rubbing with hard steel edges, or by crushing in a steel mortar, if it is very hard.

The test-tubes for dissolving the steel should have an internal diameter of 15 mm., and a length of 120 mm. The tubes are to be cleaned out by means of coarse filter-paper rolled together and well cut at the edges. 0.1 gram of the iron or steel for testing, or in the case of white pig, 0.05 gram, carefully weighed, is then put into the tube, and 2.5 c.c. or more of nitric acid of specific gravity, 1.2 added. The acid may be readily measured off in a little measuring glass of 10 mm. diameter, and 75 mm. length, and graduated so as to show whole or half cubic centimeters. The tubes are covered with small

* Only 0.0001 gram of chlorine produces a distinct yellow color in a solution of 0.1 gram of iron (from hydrated oxide of iron) in 2.5 c.c. of nitric acid. This color can be noticed even on addition of 1.5 c.c. of nitric acid and 4 c.c. of water. Upon further diluting the coloration becomes less distinguishable.

† Worn off particles from the file may, however, greatly increase the percentage of carbon in the iron.

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watch-glasses (23 mm.), and put into a cylindrical vessel of copper-plate, having a height of 100 mm., and a diameter at least of 120 mm. This vessel is covered with a copper-plate provided with a thermometer and holes for the tubes. The holes are marked with engraved figures. The vessel is to contain water and a few grams of paraffin to prevent the evaporation of the former, and is heated to 80° C. by means of a gas flame. This temperature should be kept up all the time. The tubes are shaken now and then, and the solution is completed when no further gas-bubbles appear. One and a half to two hours, or sometimes longer time, is required to effect complete solution, the time depending upon the amount of carbon in the iron.

Up to the present time this has been the ordinary way of proceeding, but it is shown by experience that the keeping up of the temperature of 80° C. requires more care than has been generally taken. Of course, this has been of less influence as long as fresh weighings of the standard steel have been dissolved along with every set of samples for testing. But if it is desired to avoid the frequent dissolving of standard steel and to use permanent standard solutions (see further down) then the iron must always be dissolved at the same temperature. For this purpose it is the safest way to put the tubes into boiling water. By this means the time for dissolving may be shortened to about three-quarters of an hour, and the color of the fluid will then turn out a little darker than by dissolving at 80° C. If, occasionally, greater rapidity is required the solution may be effected by boiling over a lamp-flame; between the flame and the tubes there should be put a brass-gauze with the tubes resting on it. The color will in this case generally be somewhat darker than when dissolved at 100° C. The reason for heating to 80° C. instead of 100° C. has been, that in the latter case there is sometimes a reddish-yellowish deposit formed on the glass; when brought down into the fluid this matter makes the solution turbid. The deposit must be dissolved by shaking if possible, otherwise it must be filtered off. It consists of nitric acid and oxide of iron. This is borne out by the fact that it also arises by heating a solution of pure hydrate of oxide of iron in nitric acid.

All gas bubbling having ceased, the tubes are taken out of the hot water and put into a beaker containing cold water. They should be covered in some way so as to be totally excluded from the daylight, which would soon give too light a color to the solutions. If protected in this way the solutions will retain their color for many

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days. The burette for determining the carbon should have 30 c.c. capacity, and be graduated into tenths of cubic centimeters, and be provided with one large and one small mouthpiece at the upper end. The solution is brought into this burette, through a filter, if necessary, as for instance if the fluid is turbid, or graphite is present. Then distilled water is to be added; the quantity of water, including the water used for cleansing the test-tube, must be at least equal to the quantity of nitric acid used, and the total volume must not be less than 8 c.c. when it is to be compared with the standard solution. The standard solution is prepared by dissolving standard steel. It should be diluted with water so as to make each cubic centimeter of the same correspond to 0.1 per cent. of carbon. It may also be carefully diluted with more water so as to have each cubic centimeter = 0.05, 0.02, 0.01, or 0.005 per cent. of carbon, of 0.1 gram of iron or steel used. For example, dissolve 0.1 gram of standard steel, containing 0.8 per cent. of carbon, in 4 c.c. of nitric acid, and add water to 8 c.c. The solution is to be carefully mixed after each addition of water; otherwise the lower part of the fluid will appear too dark. After mixing, at least one minute should be allowed for the fluid to run down the sides of the burette before reading off, which is done at the upper border of the fluid.

The above-mentioned standard solutions, representing the total, half, fifth, tenth, and twentieth of the standard, may be marked and used as follows:

	Percentage of carbon per c.c. for 0.1 gram of iron.	To be used for iron with a percentage of carbon =
N	0.10	0.8 and more
$\frac{1}{2}$ N	0.05	0.4 — 0.80
$\frac{1}{5}$ N	0.02	0.16 — 0.50
$\frac{1}{10}$ N	0.01	0.08 — 0.25
$\frac{1}{20}$ N	0.005	0.04 — 0.08

The smallest percentage of carbon* found in iron in this country is 0.04 per cent. A good daylight is required when using the last-named standard solution, and this remark applies to all colorimetric tests.

The dilution cannot be carried farther than twenty times the original solution in the case of using the ordinary burettes of about 12 mm. diameter. But one can sharply distinguish the difference in color between ordinary distilled water and a standard solution diluted to forty times its original volume, and, therefore, if one uses burettes

* By means of the iodine method 0.038 per cent. of carbon was once found in 8 grams of a Swedish Lancashire iron.

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of 24 mm. diameter, it will be possible to approximately determine the carbon in iron containing only 0.02 per cent., supposing such soft iron to be produced. In this case measure off 1 c.c. of the "N" solution in a delicate measuring tube and dilute to 40 c.c. Thus 1 c.c. will be equal to 0.0025 per cent. of carbon. Pour this standard solution into the 24 mm. tube. This tube should exactly correspond with another graduated 24 mm. tube, in which 0.4 gram of the iron for testing is to be dissolved in 10 c.c. of nitric acid, the solution diluted to 32 c.c., and then more until the colors agree. For instance, if the colors agree at 35 c.c. bulk, you find the percentage of carbon thus:

$$0.0025 \times 35 \div 4 = 0.022 \text{ per cent.}$$

Hitherto it has been the usual practice to compare colors by holding a piece of thin filter-paper behind the tubes. In this way, however, one is much dependent on the distribution of light in the room, which, therefore, ought to have for this purpose only one window. For most people's eyes the left-hand tube will appear somewhat darker than does the right-hand tube. For this reason it was originally prescribed that the tube containing the solution of iron or steel for testing should be kept to the right so as always to have it in the same position. In order to avoid being dependent on the room I work in, and to lessen the difference in color between the left and right-hand tube I now most advantageously use a contrivance in shape of a little camera, into which the tubes are put. The camera is made of wood 6 mm. thick, and is open at both ends. The inner sides are blackened. The internal height is 80 mm., width of forepart 26 mm., and width behind 120 mm. The tubes are put in the forepart through apertures in the upper part of the camera, and steadied at the bottom by a gutter of copper plate, and at the upper part by a brass-wire. The box is closed at the wider end by means of thin filter-paper* nailed to it. Burettes and tubes should be closely of the same quality as to color, etc., and be wiped with clean linen before being put into the camera.

We have of late been using as standard steels two Bessemer steels, one of which contains .80 per cent. and the other one .16 per cent of carbon. These steels are kept in pieces 12 mm. square. Samples from these pieces are always taken at right angles to the longitudinal axis The carbon in these steels was determined by me

* This can also be effected by applying a screen holding a glass adapted to the eye as to convexity or concavity, and having about 40 mm. diameter.

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by aid of the iodine-method, as described in the *Jernkontorets Annaler*, 1862, page 47. 5 grams were taken for each test. Three analyses of the harder steel showed .79, .80 and .82 per cent. of carbon, and two analyses of the steel containing .16 per cent. agreed very closely. These carbon determinations also agreed very well with those of Dr. A. Tamm, whose results by combustion are described in the *Jernkontorets Annaler*, 1874. The iodine method is now modified, so that instead of using iodine directly for dissolving the iron or steel, a solution of iodine in iodide of iron is used. This arises from the difficulty of obtaining pure iodine. The solution now used is prepared by dissolving 10 grams of iron in 50 grams of iodine, and adding another 50 grams of iodine, which is readily dissolved. The solution is filtered and water passed through the filter until a bulk of 100 c.c. is reached. 10 c.c. of this solution are required for 1 gram of iron. With regard to the diminution in weight of filter-paper on being treated with acid, we have generally used platinum filters for collecting the carbonaceous matter. However it is somewhat difficult to obtain good platinum filters, and therefore it seems preferable to use filter-paper which has been treated with hydrochloric and hydrofluoric acids,* whereby the inorganic ingredients are almost completely extracted. A filter of 60 mm. diameter thus treated does not give more than 0.0001 gram ash. The carbonaceous mass should be dried on a water-bath at a temperature of 95°–98° C. For this purpose the mass is put into a crucible, and the crucible then put into a glass tube, closed at one end and having a length of 130 mm. and diameter of 35 mm. The upper end of the tube is closed by means of a cork, through which hangs a thermometer. The crucible may be inserted or removed by means of a bent brass wire.

Even for white pig iron better results than might be expected† are now obtained by the color test. The difficulty in this case lies in the use of only 0.05 gram, and still diluting to a very large volume, which renders a slight error in observation very important. The solutions of white pig iron should be rapidly read off, because they soon become turbid with a precipitate of organic matter. This inconvenience may be, to a great extent, removed by using 7 c.c. instead of 5 c.c. of nitric acid.

The mode in which the carbon is present in the steel as "cement

* Fresenius's Zeitschrift, 1879, p. 582.

† Jernkontorets Annaler, 1874, and Berg und Hüttenmännische Zeitung, 1875, p. 440.

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carbon," or "hardening carbon," does not influence the color test otherwise than to render the solution less dark in the latter case, when the carbon is more intimately combined with the iron. Thus a steel containing 0.8 per cent. of carbon showed only 0.55 per cent. after strong hardening and crushing. After reheating the steel to a low red heat, the original percentage of carbon was again obtained. By aid of the iodine method 0.8 per cent. of carbon was found in 5 grams of the hardened steel. A piece of iron containing 0.3 per cent. of carbon, upon being hammered down cold from 12 mm. to 6 mm. square, showed the same carbon before and after hammering.

Different kinds of iron and steel behave very differently during dissolving, some solutions becoming colored at once, others only after heating. The final color, however, after diluting with water generally tallies very well with the color of the standard. In case there should be any difference in tint,—yellow or brown,—it is best to notice the intensity of colors, which can be done by holding a thin filter-paper behind the tubes, and observing through which tube one can most easily see certain dark points in the paper, etc. It is a matter of course that some persons are able to use the color test with greater advantage than others, according to their different eyesights; but eyesight may be considerably improved in this respect by practice, as shown by experience; in fact, only very few have hitherto been found incapable for this work.

The following experiments have been made with regard to the influence on color exercised by foreign substances in iron and steel:

Manganese.—0.05 gram, contained in carbonate of manganese, was dissolved in 2.5 and 5 c.c. of nitric acid. The color thus obtained was brown, owing to the presence of a little oxide of manganese. After heating to 100° C. a small precipitate was obtained (in all probability hydrated dioxide), and the solution assumed a slightly reddish color, which disappeared after diluting with water to 8 or 10 c.c. These experiments show that the color test may be used for determining the carbon in ferromanganese. A ferromanganese containing 80 per cent. of manganese showed 4 per cent. of carbon by the color test.

Phosphorus.—0.001 gram, contained in phosphate of sodium, was added to a solution of 0.1 gram of iron (as hydrated oxide) in 2.5 c.c. of nitric acid and 2.5 c.c. of water; no difference in color was noticed after this addition. Iron containing 5 per cent. of phosphorus is difficult to dissolve, and with 10 per cent. of phosphorus it is insoluble in nitric acid.

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Sulphur.—0.001 gram, contained in sulphate of magnesia, was added to a solution of iron in 2.5 c.c. of nitric acid and 2.5 c.c. of water. The color of the solution remained unaltered.

Neither did any alteration in color take place when 0.01 gram of manganese, 0.01 gram of phosphorus, and 0.001 gram of sulphur (all contained in the above-mentioned salts) were added to a solution of 0.1 gram of iron (as hydrated oxide) in 5 c.c. of nitric acid and 5 c.c. of water. The same quantities, when added to a solution of 0.1 gram of standard steel with 0.8 per cent. of carbon, did not alter the color here either.

Copper.—0.001 gram was dissolved in 2.5 c.c. of nitric acid and 2.5 c.c. of water. No coloring of the solution.

Silicon in iron and steel is, to a very great extent, dissolved in nitric acid on heating, even if lumps of silica be seen floating about at the beginning of the dissolving process. 0.4 per cent. of silicon in steel has no influence whatever on the color test. Silicious pig irons always contain graphite, which must be filtered off, together with the silica which may possibly have remained insoluble.

Tungsten in iron or steel is converted into tungstic acid (WO_3) when the iron or steel dissolves. It is insoluble, and must be filtered off.

Chromium.—0.002 gram, contained in hydrated oxide, when dissolved in 2.5 c.c. of nitric acid and 2.5 c.c. of water, gave a grayish-blue color to the solution. After addition of water to the double volume this color grew less distinct. On addition of more water the color gradually grew fainter, and at 40 c.c. it disappeared. It is difficult or even impossible to dissolve in nitric acid iron or steel containing much chromium.

Vanadium.—0.001 gram, contained in vanadic acid (V_2O_5), when dissolved in 2.5 c.c. of nitric acid, gives a faint yellow color to the solution. This color disappears after adding 2.5 c.c. of water.

Nickel.—0.001 gram, when dissolved in 2.5 c.c. of nitric acid, gives a green color to the solution. This color remains visible after adding 2.5 c.c. of water, but disappears at 8 or 10 c.c. volume.

Cobalt.—0.001 gram when dissolved in 2.5 c.c. of nitric acid gives, as is well known, a red color to the solution. After adding water to 24 c.c. this color is hardly visible, but may, however, not be considered removed before diluting to 40 c.c.

In my paper of 1862 I pointed out the desirableness of having permanent standard solutions of *inorganic* matters, instead of those prepared by dissolving burnt sugar in spirits of wine, the latter so-

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lutions getting lighter after some time, particularly after prolonged exposure to the sunlight. Many propositions have been made of late, in various journals, with regard to this matter, and compounds of iron, cobalt, and nickel, as well as potassium bichromate, have been recommended for the purpose. I have experimented upon several such mixtures, and lately, at the suggestion of Professor F. L. Ekman, I have tried the chlorides of iron, cobalt, and copper, and I find that these yield the best results, as they allow of the production of any tint in yellow, brown, or green. Such mixtures, diluted with water containing 0.5 per cent. of hydrochloric acid of 1.12 specific gravity, have been found to remain unaltered even after a long exposure to sunlight. The mixture grows more and more yellow by adding hydrochloric acid drop by drop only. I prepare my standard solutions as follows: By adding to the neutral chlorides water containing 1.5 per cent. of hydrochloric acid for the chloride of iron, and 0.5 per cent. for the two other chlorides, I prepare solutions of a strength corresponding to 0.01 gram of metal per cubic centimeter. Then 8 c.c. of the iron solution are mixed with 6 c.c. of the cobalt solution and 3 c.c. of the copper solution, and about 5 c.c. of water containing 0.5 per cent. hydrochloric acid are added to the mixture. At a temperature of 18° C.* this solution shows exactly the same color as a solution of steel in dilute nitric acid corresponding to 0.1 per cent. of carbon per cubic centimeter. The solution may afterwards be diluted with water, containing 0.5 per cent. of hydrochloric acid, to any standard color required. The addition of water is almost directly proportional to the percentage of carbon. It need scarcely be mentioned that the quantities, 0.1 gram for iron and steel and 0.05 gram for white pig iron, must be correctly weighed out when artificial standard solutions are used.

Now that permanent standard solutions can be obtained, it seems to be the right time to apply the old method for the determination of copper in ammoniacal solutions. This method was adopted by Mr. J. Blodget Britton, of Philadelphia (*Fresenius's Zeitschrift*, 1871, p. 245),† for colorimetric tests on iron and steel. He uses several tubes of the same size and quality, having equal volumes of standard solutions of different strengths in the different tubes; he dissolves

* This is an addition made since the paper was published in the Jernkontorets Annaler.—M. T.

† From Mr. F. O. Söderberg, at the School of Mines, Stockholm, standard solutions, artificially prepared, as well as standard steels, are obtainable. The permanent solutions are kept in closed glass tubes, to each of which belongs a

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the steels for testing in similar tubes, and finally dilutes these solutions with water to the same volume as the standard solutions. By comparing these he is able at once to determine to the hundredth of one per cent. by using 1 to 2 grams for each test. For his standard solutions he used burnt coffee, which he considered to be better than burnt sugar.

Greater accuracy in color tests may also be obtained by looking at the solutions in the tubes from above, instead of from one side. In this case, however, the bottoms of the tubes must be perfectly alike. A suitable light must be provided, and the columns in the tubes must all have the same height.

I trust that a strict observation of the directions now given will essentially remove the difficulties which have been experienced in using the color test, as well in this country as abroad. It should also be borne in mind that the properties of iron and steel are not dependent on the amount of carbon alone.

Before concluding this paper I have to thankfully acknowledge the service rendered by Mr. C. G. Dahlerus, mining engineer, in working out the results now published.

DISCUSSION ON CHEMICAL METHODS OF ANALYZING RAIL-STEEL.

AUSTIN FARRELL and JAMES GAYLEY, Missouri Furnace Co., South St. Louis, Mo : The discussion of chemical methods for the analysis of iron and steel, which has been one of the results of Dr. Dudley's papers on steel rails, bids fair to be of great value in instituting comparisons of the methods in use in the laboratories of our numerous iron and steel works. We have found, in our experience in making comparative determinations (especially of phosphorus) with other chemists, that the greatest variations in results are caused by the use of different methods. One case in particular has come under our observation where there was a marked difference in results from two laboratories, but a close agreement was subsequently obtained by the adoption of the same

corresponding burette. Those having burettes may send them to him in order to get suitable tubes for the standard solutions.

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method. An analysis, at the present stage of iron and steel manufacture, is not, as it formerly was, a matter of curiosity, but represents dollars and cents, and that not only in the disposal of the product, but in the economy of every-day working. It is of the utmost importance, then, that chemists connected with iron and steel works should agree upon standard methods, which, if not generally accepted, may be resorted to as decisive in adjusting the difficulties which so often arise between buyer and seller. The paper of Mr. Troilius is of great interest, as it gives the methods in daily use in iron manufacturing districts abroad. In accordance with Mr. Sandberg's suggestion, and at the request of the Secretary of the Institute, we give a description of the methods used in our laboratory in the analysis of Bessemer pig iron.

Phosphorus Determination.—2.5 to 3 grams of iron borings are treated with nitric acid (sp. gr. 1.2), using 10 c.c. of acid for each gram taken, and heated on a sand-bath until effervescence ceases; 5 c.c. of hydrochloric acid (sp. gr. 1.12) for each gram of iron are then added, the solution evaporated to dryness, and heated in an air-bath for one hour at a temperature of 120° C. Take up with the least possible amount of concentrated hydrochloric acid, and when the oxide of iron is dissolved, add nitric acid and drive off the hydrochloric acid by evaporation, adding a little nitric acid from time to time. Finally, concentrate to small bulk and then dilute sufficiently to prevent the acid from attacking the paper, and filter; or, what is preferable, filter through asbestos, using a Bunsen pump. If the bulk of the filtrate is too large, concentrate by evaporation; nearly neutralize with ammonia, add molybdate solution, and allow to stand on a water-bath from 20 to 30 minutes; then put the beaker in a warm place for 2 or 3 hours. If the solution is nearly neutral, a complete precipitation takes place. The yellow precipitate, after being thoroughly washed, is dissolved in ammonia, the filtrate nearly neutralized with hydrochloric acid, slightly warmed, and allowed to stand from 1 to 2 hours in order to separate any silica which may be present. It is again filtered, if necessary, magnesia-mixture added, stirred vigorously, and allowed to stand until the supernatant fluid becomes clear. It is then filtered and ignited while still wet. Below are some comparative analyses, made in connection with chemists at different Bessemer works, using the molybdate method, and reprecipitating with magnesia-mixture. As we have not these chemists' permission we cannot give their names:

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Missouri Furnace Co.	Bessemer Works.
0.112	0.114
0.052	0.053
0.145	0.141
0.131	0.132
0.098	0.100

In the method of determining phosphorus by weighing the yellow precipitate directly we find that the results obtained are too high. It is an interesting fact which we have noted, that in laboratories where this direct method is generally used, the double precipitation is resorted to in cases of special importance.

Sulphur Determination.—In the determination of sulphur we generally use Dr. T. M. Drown's method,* and find it very satisfactory. Recently we have used with much success, on low-sulphur irons, Elliot's method as described in the communication of Mr. Emmerton.

Silicon Determination.—Weigh out into a small-sized beaker from 0.5 to 1 gram of iron borings. Add from 8 to 12 c.c. of water, and from 1 to 2 c.c. of concentrated sulphuric acid; heat until effervescence ceases, then add from 1 to 2 c.c. of concentrated nitric acid and evaporate to dryness. Moisten with concentrated hydrochloric acid; add from 20 to 30 c.c. of water; boil until the iron salts dissolve; filter, wash three times with warm water, twice with boiling water containing 5 per cent. of nitric acid, and then twice with warm water, and ignite without drying. The average time for making a determination is from seventy-five to ninety minutes. The results obtained are very satisfactory.

Manganese Determination.—We use the method described by Mr. Ford,† and find the results very satisfactory.

J. W. CABOT, Johnstown, Pa.: *Carbon Determination.*—When all the necessary precautions are taken, the Eggertz color-test is doubtless very satisfactory and accurate for carbon in rail-steel; but it may also give very wild results if these precautions are neglected.

In dissolving the steel, if the acid is poured on in such a way as to become very hot, there is danger of a loss of carbon-color. Some of the iron may also be converted into a difficultly-soluble oxide. These two sources of error can be avoided by pouring the steel-borings into the acid instead of the acid on to the steel, so that there will always be a large amount of acid with a small amount of undissolved

* *Transactions*, vol. ii, p. 224.

† *Transactions*, vol. ix, p. 397.

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steel, the dissolving vessel being kept cool by standing in water. It does not seem to be of importance whether the final dissolving is done at 90° or 100° C., provided the time is varied correspondingly; the higher the heat used the less time being allowed. In fact, a very satisfactory way, I have found, is to boil the acid solution gently over a lamp for about eight minutes. This will insure the complete solution of the carbide of iron, and in a number of comparative trials has given the same intensity of color as the same steel dissolved at a lower temperature and in longer time. The fact that the carbide and oxide of iron sometimes dissolve with difficulty is another source of error. It is desirable to filter the solution before comparing, to free it from suspended silica.

In regard to the amount of steel taken for analysis, it would seem that it should be at least 0.5 gram, for the reason that slight inaccuracies in the weighing and subsequent treatment would not so largely appear in the result as they would if only 0.1 gram, or 0.2 gram was taken. If a full gram is used the possible error is divided by ten; and this is no mere distinction without a difference, for the fact must be considered that this kind of work is done, and must always be done, by persons who are not analysts.

Judging the color of the solutions by means of a rack of graduated standard solutions is, I think, more rapid and more convenient than comparing with a standard steel dissolved each time. In order to use the latter method it is necessary, in extensive practice, to have a large piece of steel standardized, and, if it is true, as I presume will not be disputed, that the carbon content of different parts of a large piece of steel—especially Bessemer steel—varies as much as 0.02 per cent., the standard itself may introduce such an error into the estimation. Of course it would not do to take the average carbon content, unless it were possible to use, with every set of estimations, standard borings which would be a fair average sample. By working with standard solutions this difficulty can be obviated in part, because a much smaller, and presumably more homogeneous piece of steel may be used as a standard. If sufficient care is taken in the preparation of the fixed standard, so that it remains fixed, or is corrected before it gets more than 0.01 per cent. from the truth, this latter method seems to be even more accurate than the other.

By having a series of colors made, as Professor Eggertz suggests, with inorganic solutions, graduated to every two-hundredths of a per cent. from 0.20 to 0.50 per cent., and testing the permanency of the colors by means of at least two small standard steels, at stated inter-

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vals, and observing all the conditions, carbon estimations, accurate to 0.01 per cent., can doubtless be made with great facility.

Manganese Determination.—The following method for the estimation of manganese, given somewhat in detail, has proved in a large number of cases to be very accurate and satisfactory.

One gram of steel is dissolved in 15 c.c. of nitric acid (sp. gr. 1.2) in a small beaker, evaporated to about 10 c.c., then diluted and poured into a large flask and further diluted to about 750 c.c. Acetate of soda is added till the solution becomes deep red; then, about as much more of the acetate. This is boiled a minute, and the precipitate allowed to settle, the flask being laid on its side. The clear liquid is poured through a large plaited filter, and the precipitate dissolved in 15 c.c. of nitric acid, and a second separation made, the whole contents being then thrown on the filter; ammonia is added to the filtrate until there is a distinct precipitate, and then bromine-water (4 to 5 c.c.), drop by drop. After standing a few minutes the solution is heated to boiling, being constantly stirred to make the precipitate collect, and bromine-water added at intervals. After boiling five minutes the lamp is placed at one side, which causes the precipitate to roll into a ball on the other side of the beaker, which allows the clear filtrate to be siphoned off and the precipitate to be washed very thoroughly with hot water. If the filtrate shows no yellow tint it is entirely free from manganese.

Of many tests made of such filtrates no instance of manganese remaining in the solution has been found. This precipitate will contain, besides the mixed oxides of manganese, invariably traces of oxide of iron and silica, and sometimes traces of cobalt and nickel. But, as the last two seldom occur in weighable quantities, the precipitate need only be corrected for iron and silica. After igniting at a heat approaching whiteness for fifteen minutes, and weighing as Mn_3O_4, it is dissolved in hydrochloric acid, the chlorine boiled off, acetic acid (or acetate of ammonia) added, and the iron precipitated with ammonia, and filtered off with the silica. A trace of manganese is often thrown down with the iron, so that it must be dissolved on the filter and again precipitated and filtered on to the same filter, washed, ignited, and weighed. When this is subtracted from the gross weight there is left the true weight of Mn_3O_4. If nickel and cobalt are present, in weighable quantities, they must of course be estimated and subtracted from the first weight. The method is not as rapid as could be desired, requiring three or four

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hours for completion, though a dozen estimations may be made in a day.

Phosphorus Determination.—For ordinary rail-steel, I think a very good way is to take 1 gram for analysis, as more than this gives so large a bulk of precipitate that it is not conveniently washed. In precipitating I think it advisable to use a large excess of molybdate solution, and allow it to stand at least three hours, at a heat of about 90° C. Instead of brushing off, or igniting the phospho-molybdate, it seems to me preferable to dry and weigh the filter and precipitate in a light weighing-tube with ground-glass cover. Duplicates done in this way should not differ more than 0.002 per cent.

F. P. DEWEY, Washington, D. C.: *Carbon Determination.*—For the rapid estimation of carbon I use the Eggertz color-test with a single standard prepared from caramel, the color corresponding to 0.01 per cent. per cubic centimeter on a gram. The solution of steel is prepared in the ordinary way at a temperature of 87° C., and the comparison made, when solution is complete, as rapidly as possible, with a minimum exposure of the apparatus to the light. Although I have used this method a great deal, I am not thoroughly impressed with its accuracy, but its rapidity recommends it highly where a great many determinations are required daily. My lack of confidence in the method arises from an occasional anomalous result, and also from the lack of agreement in the results obtained by different chemists working on the same sample. Mr. Troilius and others claim that results accurate within 0.01 per cent. can be obtained; this I doubt very much, and even if such accuracy can be obtained, it is not the rule. My own experience, and the recorded experience of others, show that it may give percentages widely different from the truth. On the other hand, when working on one class of steels of nearly the same percentage the results are strictly comparable, though not always as close as 0.01 per cent.; and this fact, combined with its rapidity, eminently fits it for a steel-works' method. I do not wish to be considered as condemning the method, but I am convinced that the accuracy claimed for it has been over-estimated, and that its proper function is simply to control at the works.

The following are results in my possession obtained by the chemists of both English and American steel-works.

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	Chemist.				
	A.	B.	C.	D.	E.
Steel No. 1. (Same sample throughout.)	0.16	0.10	0.14		
Steel No. 2. (Same sample throughout.)	.....	.....	.....	0.37 0.39 0.38 0.39	0.45 0.44 0.42 0.44
Steel No. 2. (Another sample.)	0.35 0.39				

When the greatest accuracy is required I much prefer to dissolve the steel in ammonio-cupric chloride, and burn the residue in oxygen gas in a porcelain tube. This is necessarily a longer process, but when a number of determinations are made at once, only a small amount of time is consumed by each determination.

Phosphorus Determination.—I have two methods for phosphorus, depending upon the time in which a result is required. For controlling the run of the works I proceed as follows: Not less than two grams are dissolved in nitric acid (sp. gr. 1.2), with the addition of a small amount of dilute hydrochloric acid, and the solution evaporated to dryness. When thoroughly dry the residue is heated to 120° to 130° C. for an hour and a half. This residue is generally considered as insoluble in nitric acid, but in the last three years I have never once failed to bring it into solution by adding a moderate amount of strong nitric acid (sp. gr. 1.4), covering securely, and warming gently for ten to twenty minutes, according to the amount of steel taken. After solution, the excess of acid is evaporated off until a thick syrup is obtained, which is diluted sufficiently and filtered. The filtrate is treated with ammonia until a slight permanent precipitate is formed, the necessary amount of a nitric acid solution of molybdic acid is added, and the whole kept warm and agitated occasionally for two to three hours, at the end of which time the precipitate is filtered off and weighed. It has been my plan to filter through counterpoised filters, wash with water containing 1 per cent. of nitric acid, dry at 120° C., and weigh; but since the introduction of the Gooch filtering crucible I have been very much pleased with its working, and propose, in the future, to filter through that, and avoid all weighing of paper. In the case of steels low in silicon, especially soft steels, the evaporation to dryness may be omitted, by which means the process is very much shortened. The second

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method allows the molybdic precipitate longer to separate, and the fluid is kept warmer. After filtering, the precipitate is dissolved in ammonia, and the phosphoric acid precipitated by magnesia-mixture and ammonia. The time allowed for this precipitate to separate is dependent in a great measure upon the amount of agitation which can be given the fluid. With a great deal of agitation it may safely be filtered in three hours, and I suppose with constant agitation it might be filtered sooner. I regard the second method as much more accurate than the first, the objection to the first being the liability of incomplete precipitation of the phosphorus from the lack of sufficient heat, or, what is more common, the precipitation of free molybdic acid from an excess of heat.

Silicon Determination.—I have been in the habit of dissolving in aqua regia, evaporating and separating in the usual way, and fusing the residue with mixed carbonates, but I have recently tried the nitric and sulphuric acids method of Dr. T. M. Drown, and propose to adopt it permanently.*

Manganese Determination.—I use the method given in Mr. Kent's paper at the Staunton meeting, under Chemist I. It is as follows: "A slight permanent precipitate is formed in the solution by sodium carbonate, then 4 c.c. of acetic acid (sp. gr. 1.04) added for each 500 c.c. of final solution. As soon as the precipitate is dissolved, the solution is diluted with hot water to 500 c.c. for each 0.5 gram of iron or steel. The solution is then brought to the boiling-point, when the requisite amount of sodium acetate is added, the whole is boiled for a few moments, and allowed to settle. When nearly clear, as much as possible of the solution is poured through a ribbed filter, boiling water is added to the precipitate, and the whole again brought to the boil, when it is allowed to settle, and the solution poured through the filter. It is washed again twice by decantation, with the addition each time of 0.5 c.c. of the same acetic acid; the precipitate is then brought on to the filter and washed with boiling water until free from chlorides. The filtrate is allowed to stand on the steam-bath over night. When dry, the residue is taken up in water with addition of about 1 c.c. of acetic acid. By this process any iron in the filtrate will be left undissolved, and can be filtered off. If I am in a hurry (instead of evaporating to dryness) I add a little sodium carbonate solution and evaporate to a suitable volume; the manganese is then precipitated with bromine. . . . . The man-

* *Transactions*, vol. vii, 437; vol. viii, 508.

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ganese is filtered off and weighed as Mn_3O_4. . . . . The amount of alkali that it contains is very small, and when the percentage is under 2, the error from that cause is too small to be considered. I made a series of tests on that subject by weighing the manganese first as Mn_3O_4 and then as $Mn_2P_2O_7$, and found that up to 2 per cent. the difference was very small."

While the results given in Mr. Kent's paper seem to be strongly against the method, I am yet to be convinced that there is a uniformly better method. I have tried the precipitation of manganese by potassium chlorate in strong nitric acid solution, and am quite favorably impressed with it, but I am not familiar enough with it yet to express a decided opinion. In regard to the precipitation of manganese by ammonia and bromine combined, in the presence of ammoniacal salts, I may say that I have used that process for the estimation of the small amounts of manganese occurring in many native silicates with excellent results.

Sulphur Determination.—I have two methods, a rapid and a slow one. When in a hurry I dissolve five grams or more of steel in hydrochloric acid, and pass the gas through an ammoniacal solution of cadmic sulphate. As soon as solution is effected the acid is boiled, and the evolution flask is filled with boiling water. The cadmic sulphide precipitated is then filtered off on counterpoised filters, washed first with water containing ammonia and then with water, dried at 100° C., and weighed. This is not a rigidly exact method, but as results can be obtained in two or three hours it has its advantages. When accuracy is required I use the method of Dr. T. M. Drown,* the steel being dissolved in hydrochloric acid, and the gas passed through potassic permanganate, and the sulphur precipitated as baric sulphate. For this process I keep a separate bottle of acid and one of potassic permanganate, in which I determine the amount of sulphuric acid, and always apply the suitable correction to the analysis. I have seen the bromine process used with very satisfactory results. Of all the methods described by Mr. Troilius it seems to me that his method for sulphur is the only one open to very serious objection, and the precipitation of a small amount of baric sulphate in the presence of a large amount of iron certainly is a very grave objection. I have frequently had considerable trouble in freeing baric sulphate from iron where the proportion of iron to sulphate was much less than in this case, even when using much

* *Transactions*, vol. ii, p. 224.

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more than "some drops of hydrochloric acid" in the wash-water, and washing many times by decantation.

J. B. MACKINTOSH, Hoboken, N. J.: *Carbon Determination.*—Since I never have enough steels at one time for analysis to render it worth while to prepare standard solutions, I use the combustion method. Two grams of the sample are treated with a concentrated solution of cupric chloride, with the addition of enough ammonia to produce a permanent precipitate, and, finally hydrochloric acid is added, and, if necessary, more copper solution to dissolve the precipitated copper. The solution is filtered through an ordinary small funnel, loosely stopped with asbestos, and washed with hydrochloric acid and water as usual. The filter is then dried in an air-bath. When dry the asbestos, with most of the carbon, is placed in a platinum boat, and the carbon which remains attached to the side of the funnel is collected together by a small bunch of slightly moistened asbestos and added to the rest. The combustion is performed in a stream of oxygen, and the resulting carbonic acid is absorbed by soda-lime.

Phosphorus Determination.—I dissolve, according to the sample, from 2 to 10 grams of steel in a mixture of nitric and hydrochloric acid on a sand-bath, boil the solution with occasional addition of hydrochloric acid till all the nitric acid is destroyed, and evaporate to dryness. The residue is then redissolved in hydrochloric acid, water is added, and sulphuretted hydrogen passed into the solution till the iron is reduced to the ferrous condition. In order to do this it is necessary that the nitric acid should have been perfectly expelled, for otherwise the sulphuretted hydrogen will be decomposed, with separation of sulphur, a little nitric acid acting as in the manufacture of sulphuric acid, being continuously destroyed and as continuously regenerated. By this operation any arsenic which may be present in the solution will be separated as sulphide, and will not be present with the phosphorus in the subsequent stages of the process.

The solution is then boiled to expel the excess of sulphuretted hydrogen, and without filtering off the sulphur and sulphide of arsenic, if present, a few cubic centimeters of permanganate solution are added, and then ammonia in quantity sufficient to precipitate all the ferric oxide in the solution, and with it all the phosphoric acid.* This precipitate is filtered as rapidly as possible, and without washing is dissolved in hydrochloric acid, and the sulphur, etc., filtered out.

* I have since found that small quantities of phosphoric acid pass into the filtrate, which may be regained by repetitions of the precipitations.

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Nitric acid is then added to the solution, which is boiled to peroxidize the iron, and then ammonia, and the filtered precipitate, once washed, is dissolved in nitric acid. This solution is, if necessary, concentrated to about 50 c.c., and the solution of molybdate of ammonia is then blown forcibly into it from a pipette, which will prevent the precipitation of the molybdic acid.

The molybdate solution used is made by dissolving about 130 grams molybdate of ammonia in 1000 c.c. water, with the addition of a little free ammonia. Ten cubic centimeters of a solution of this strength should precipitate about 0.02 gram of phosphorus.

The solution is then heated, though not to boiling, is removed from the source of heat and ammonia gradually added till the yellow precipitate forms; then, if any iron has been precipitated, it is redissolved with nitric acid in slight excess. After standing on top of the air-bath for 3 to 4 hours it is filtered and washed with a solution of nitrate of ammonia slightly acidified with nitric acid. The filtrate is allowed to stand over night, with fresh addition of molybdate solution in case the precipitation has not been complete.

The precipitate, after having been thoroughly washed, is dissolved in ammonia. Any iron which may be present is dissolved in hydrochloric acid and a few drops of citric acid, and the solution made alkaline with ammonia and added to the main portion. The solution is allowed to stand for an hour, then filtered, and magnesia-mixture added, and the precipitated ammonium-magnesium-phosphate treated as usual.

Sulphur I determine in the same manner as Mr. Troilius; manganese by acetate of soda and bromine; and silicon by the aqua regia method.

BENJAMIN B. WRIGHT, Pittsburgh, Pa.: *A Volumetric Method of Estimating Phosphorus.*—Three grams of steel, or less, are dissolved in 30 c.c. of nitric acid (sp. gr. 1.2), the solution is dried on a sand-bath, and heated till no more fumes are given off, in order to destroy any organic matter. The dried mass is then dissolved in strong hydrochloric acid, and the solution evaporated to small bulk by boiling. The boiling will change any pyrophosphoric acid, formed by the heating, back to the ordinary phosphoric acid. The solution of iron is allowed to cool and a strong solution of ammonium nitrate added. This solution is made by dissolving 600 grams of chemically pure ammonium nitrate in water and diluting to a liter; 10 c.c. of this solution are added for each gram of metal originally taken.

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The solution of iron is then filtered into a beaker and about 15 c.c. of water are added. The solution is now ready for precipitation. I have found that the above large amount of ammonium nitrate insures the precipitation of all the phosphorus, notwithstanding the presence of hydrochloric acid in the solution. The solution is then heated on a water-bath to between 75° and 85° C., and the phosphoric acid is precipitated by the addition of from 20 to 25 c.c. of a nitric acid solution of ammonium molybdate, made according to the formula in Fresenius's Analysis. The solution is kept at the above temperature for one hour, when the precipitation will be complete. It is important that the solution be kept between the above limits of temperature, as a lower temperature than 75° C. will not complete the precipitation in an hour; while a higher temperature than 85° C. will precipitate molybdic acid. The yellow precipitate is filtered off and washed with a six per cent. solution of ammonium nitrate till free from iron.

The precipitate is then dissolved in dilute ammonia, and the solution transferred to a flask. 50 c.c. of dilute sulphuric acid are added, and from 5 to 10 grams of granulated zinc, and the solution is boiled hard for 30 minutes. The action must be vigorous to insure the complete reduction of the molybdic acid, and if the zinc is all dissolved before that time more must be added. At the end of the thirty minutes the reduced solution is poured off from the zinc, if it is not all dissolved, and titrated directly with standardized potassium permanganate solution, and the amount of phosphorus in the steel calculated directly from the number of cubic centimeters of permanganate used.

The solution when ready for titration is almost black from the sulphate of sesquioxide of molybdenum formed by the reduction of the molybdic acid; but on the addition of the permanganate the color is entirely discharged, and the usual pink end-reaction of the permanganate can be clearly seen.

I have found by careful analyses that the precipitate made by the above method is of absolutely uniform composition, and that the amount of phosphorus in it is 1.54 per cent. of the amount of molybdic acid; so that if the molybdic acid in the precipitate be determined, the amount of phosphorus may readily be calculated from it.

In standardizing potassium permanganate for this analysis iron wire is used. According to Wernike,* the iron standard multiplied

* Fresenius's Zeitschrift, xiv, p. 1.

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by .903 equals the molybdic acid standard; and from my analyses the amount of molybdic acid in the precipitate, multiplied by .0154, equals the phosphorus in grams. Then by multiplying the amount of iron represented by 1 c.c. of the permanganate by the product of these two numbers (.0139) the amount of phosphorus represented by each cubic centimeter is found. The permanganate should be of such strength that 1 c.c. equals about .0075 grams of iron; then 1 c.c. will represent about .0001 gram of phosphorus.

In making the analyses on which the above figures are based I determined the phosphorus in the yellow precipitate by the usual magnesia-mixture, with the necessary precautions to avoid the presence of molybdic acid in the pyrophosphate of magnesia, and in the filtrate from this precipitate determined the molybdic acid volumetrically.

Three hours and a half are generally required to complete an analysis for phosphorus in steel by this method. Pig irons require about fifteen minutes more on account of the difficulty of filtering the solution. The time on an analysis of steel is divided about as follows:

	Hours.	Minutes.
Weighing, dissolving, and transferring to dish,	0	15
Drying,	1	
Dissolving, adding ammonia nitrate, and filtering,	0	15
Precipitation,	1	
Filtration and washing,	0	15
Reduction,	0	30
Titration,	0	5
	3	20

I have made two analyses for phosphorus by this method, carrying on the operations together, in 3 hours 35 minutes.

In conclusion I can give the following results of comparative analyses which I have made; those in the first series being made by the use of molybdic acid and double precipitation, the phosphorus being determined as magnesium pyrophosphate; those in the second series being made by the above volumetric method:

Irons and Steels.	By Gravimetric Analysis.	By Volumetric Analysis.
No. 1,	.070	.070
2,	.085	.084
3,	.087	.084
4,	.071	.070
5,	036	.033
6,	.024	.023
7,	.125	.125

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The following analyses were made by my assistants:

8,	.087	.083
9,	.032	.031
10,	.163	.152

F. A. EMMERTON, Joliet, Illinois.—The following are the methods used in the analysis of steel in the laboratory of the Joliet Steel Company:

Carbon Determination.—One gram of steel is used for each test, the drillings being put in test-tubes 8 inches long, and 1 inch diameter, set in a suitable rack; 15 c.c. of nitric acid (sp. gr. 1.2), are run into each tube from a pipette, the tubes in the rack being partly immersed in cold water to prevent the reaction being too violent. The tubes are closed loosely with glass bulbs, a little larger than the mouth of the tubes, and are set in a water-bath kept at 90° C. for a half hour. The rack containing the tubes is then set in a pan of cold water to cool the solutions, which, in a few minutes, are filtered through 3½-inch filters into a set of test-tubes, 5 inches long, and as near as possible $\frac{5}{8}$ inch diameter. The colors are then compared with a set of standard colors, corresponding to every even hundredth of a per cent., ranging from .16 per cent. to .44 per cent. The standard colors, of course, are kept in tubes of the same size as those into which the solutions to be tested are filtered, and are made from a mixture of the solutions of burnt coffee and caramel in alcohol diluted with its own volume of water, and are found not to vary more than .02 per cent. in a month. They are renewed generally every three or four weeks, oftener in summer, and less often in winter.

Tests showing more than .44 per cent. carbon are made by diluting to half strength with water, and comparing with standard colors, doubling the readings obtained. Tests showing less than .16 per cent. carbon are made by comparing in graduated comparison-tubes, with a diluted solution of steel, the percentage of carbon in which has previously been determined by comparison with the standard colors.

I prefer using one gram of steel for the tests to a smaller amount, as the error from dirt in the drillings and from careless weighing are rendered less in effect. On account of the length of the tubes in which the solution takes place, and their being stoppered with glass bulbs, loss from evaporation amounts to nothing, and the filtering of the solutions does away with an error caused by fine scale in suspension.

Silicon Determination.—The method is essentially that of Dr. T.

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M. Drown, though the solution is made at once in a mixture of 1 part concentrated sulphuric acid, and 4 parts nitric acid (sp. gr. 1.2); 20 c.c. of this mixture suffice for the solution of 1 gram of steel. The watch-glass is allowed to remain on the dish, which is pushed on to a hot part of the sand-bath, where the solution goes down to dryness in less than fifteen minutes. The watch-glass prevents loss from spattering, and by so doing allows the solution to be boiled down in less time than it could be brought to dryness otherwise. Determinations made in this way can be completed in less than forty-five minutes with the use of the filter-pump, which I use in all filtrations.

Sulphur Determination.—The method used for sulphur is that of A. H. Elliott.* Five grams of steel are dissolved in about 80 c.c. hydrochloric acid (1 in 2), in a 300-c.c. flask. The evolved gas is led through a solution of pure caustic soda free from sulphides, which absorbs the sulphuretted hydrogen as sulphide of sodium. About 40 c.c. of the caustic soda solution (1 in 5) are used, and it is arranged in bottles or tubes, in such a way that the gas shall bubble through it at least twice.

The steel may be dissolved quite rapidly without fear of any sulphur passing the caustic soda unabsorbed. The solution in the flask is brought to boiling, and as soon as the steam rises to the stopper the flame is taken away, and air is aspirated through the apparatus for a few minutes. The caustic soda is washed out into a 500-c.c. beaker, and made up with cold water to 200 or 300 c.c. It is then acidified with strong hydrochloric acid, which liberates the sulphuretted hydrogen retained in solution by the large excess of liquid present. Starch solution is added, and the sulphuretted hydrogen titrated with a standard solution of iodine, each cubic centimeter of which equals about .0005 gram sulphur.

If much sulphur is present the liquid takes on at first a reddish color, due to the finely-divided separated sulphur, but at the end the blue color of the iodide of starch comes out plainly, and the titration may be stopped accurately with the last drop.

The iodine solution is made by dissolving 5 grams of iodine with the aid of 7 grams of potassium iodide in a little water, and diluting to a liter. Its strength is found by titrating against a hyposulphite solution of known strength. The latter is made by dissolving 25 grams of hyposulphite in a liter of water, to which about 2 grams of

* Chemical News, vol. xxiii, p. 61.

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ammonium carbonate are added to prevent the solution from changing. The strength of the hyposulphite solution once ascertained, it is a simple matter to find the value of the iodine solution at any time. The hyposulphite solution may also be standardized, as suggested by Elliott, by means of a solution of potassium bichromate.

The hyposulphite solution prepared as described may be relied upon to retain its strength without essential change for several months at least; and the iodine solution does not need to be tested oftener than once in three or four weeks if kept properly stoppered. The testing of the iodine solution, however, need not take more than five minutes.

The caustic soda used for absorbing the sulphuretted hydrogen should be free from sulphide, and may be readily tested for its presence by acidifying some of the solution, adding starch as in regular titration for sulphur, and then adding a drop or two of the iodine solution. If the caustic soda is free from sulphide, the blue color should be formed and remain after the addition of the first drop. There is, however, very little difficulty in obtaining caustic soda which will stand the above test.

This method is both accurate and rapid, and very satisfactory in use, for in duplicate determinations it invariably gives the same results, agreeing to the third place of decimals. I have compared this method with one described by Fresenius,* which, he says, agrees perfectly with the acetate of lead method. It consists in passing the gas evolved from the solution of steel in hydrochloric acid through a sufficient quantity of a solution of bromine in strong hydrochloric acid. This solution of bromine oxidizes the sulphur completely to sulphuric acid. The bromine is subsequently boiled off, and the greater part of the hydrochloric acid evaporated, the residue diluted with hot water, and the sulphuric acid precipitated by barium chloride. I obtained the following results in comparing the two methods:

Sample.	Elliott's Iodine Method.	Fresenius's Bromine Method.
No. 1, ...	.309 Sulphur, per cent	.296 Sulphur, per cent.
2, ...	.089 "	.091 "
3, ...	.070 "	.074 "
4, ...	.008 "	.007 "

If there is an error in this method it is one inherent in several methods in common use, and that is a slight loss due to the sulphur which remains in the solution, and in the insoluble residue in the

* Fresenius's Zeitschrift, vol. xiii, p. 37.

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flask. This error, however, is inconsiderable, and not as great as is likely to arise from impurity of the barium sulphate in methods depending on the precipitation of the sulphur by barium chloride. The method requires very little attention and may be completed in half an hour, though in my laboratory it generally takes about forty-five minutes to carry out a determination from beginning to end.

Phosphorus Determination.—10 grams of steel are dissolved in about 150 c.c. of nitric acid (sp. gr. 1.2) in a beaker of about 800 c.c. capacity. After a few minutes the beaker is pushed on to the hottest part of the sand-bath, the cover taken off, and the solution boiled down to dryness in less than an hour. The beaker is kept on the sand-bath for about a half hour longer, then taken off and cooled, and sufficient strong hydrochloric acid added to dissolve the dry mass. The beaker is set on the sand-bath again, heated near boiling for a few minutes, and after complete solution, diluted with two or three times its volume of cold water. The acid is now completely neutralized with strong ammonia, the precipitated oxide of iron dissolved in a slight excess of strong nitric acid, and about 80 c.c. of molybdate solution added. The beaker is set away in a warm place for at least four hours. The yellow precipitate is caught on a filter, washed with dilute molybdate solution and dissolved in ammonia (1 in 4). A small beaker is set under the funnel containing the precipitate, some dilute ammonia is poured on to the filter and then a hole is punched through the point of the filter and all its contents washed into the beaker by means of more dilute ammonia contained in a small wash-flask. A slight excess of magnesia-mixture is then added, and the beaker set away for two hours at least. The precipitate is then caught on a filter, slightly washed with dilute ammonia, and dissolved in hydrochloric acid (1 in 2), the solution in this case filtering through the paper into a beaker in which has been placed a small pinch of citric acid. The filter is washed two or three times with hot water, and the filtrate neutralized with strong ammonia, and then one-third of its volume of strong ammonia added. The beaker is set aside for at least four hours, and eventually the precipitate collected on a filter, which is thrown wet into a weighed platinum crucible, in which it is ignited. After the filter is burnt the precipitate is treated with a drop or two of nitric acid, which leaves the pyrophosphate perfectly white. This method may be carried out accurately in twenty-four hours, and never requires more than thirty hours for its completion.

Manganese Determination.—The manganese method is essentially

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that described by Volhard,* and tested by Alexander E. Haswell.† I use the method in the following way: 1.2 grams of steel are dissolved in a porcelain dish with 25 c.c. of a mixture of 1 part concentrated sulphuric acid, and 4 parts nitric acid (sp. gr. 1.2). Boil down, with the cover on the dish, on a hot place on the sand-bath, and heat 2 minutes, while white fumes of sulphuric acid are given off, to destroy carbonaceous matter. Dissolve in a little hot water, taking care not to leave any basic sulphate of iron undissolved. Wash into a flask graduated to hold 300 c.c., and add to the solution zinc oxide held in suspension in water. After each addition of the zinc oxide the flask is shaken, and then allowed to stand a few seconds. As soon as all the acid has been neutralized by the zinc oxide, the precipitate settles readily and leaves a supernatant liquid which is not at all cloudy. The iron then is completely precipitated in combination with zinc oxide, and all the manganese remains in solution. After cooling the flask, which during the neutralization gets somewhat heated, the contents are diluted with cold water to the mark. The liquid is then thoroughly mixed by pouring from the flask into a beaker and back again, once or twice, and is then filtered through a ribbed filter into a dry beaker. 200 c.c. of the filtrate are drawn out with a 200 c.c. pipette, and transferred to a flask holding about 400 or 500 c.c. This quantity contains two-thirds of the manganese in the steel taken for analysis. The result, consequently, is reckoned on .8000 gram of steel.

The liquid is now ready to be titrated with permanganate of potash, the reaction which takes place being as follows:

$$3MnO + Mn_2O_7 = 5MnO_2.$$

A permanganate solution is used, each cubic centimeter of which precipitates about .0010 gram of manganese. The solution in the flask is heated nearly to boiling, taken away from the heat, and one drop of strong nitric acid, or two drops of acid of 1.2 sp. gr., added. Permanganate is then run into the flask in quantity nearly sufficient to complete the precipitation of the manganese. The flask is well shaken for a few seconds to facilitate the settling of the precipitated MnO_2, which collects in large flocks that readily sink to the bottom. As long as any manganese remains unprecipitated, the supernatant liquid will be colorless. As the titration nears the end, however, it will be found that the permanganate does not lose its color at once,

* Liebig's Annalen, No. 198, p. 318; Fresenius's Zeitschrift, vol. xx, p. 271.

† Dingler's Polytechnisches Journal, No. 235, p. 387.

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and that the flask has to be shaken a little longer than at first to give time for the reaction to take place. When all of the manganese is precipitated, and a drop of permanganate remains in excess, its pink color is readily seen, and remains unchanged in the liquid for some minutes. If too much time has been taken for the titration and the liquid has got too cool, the precipitated MnO_2 does not collect readily, and it is necessary to heat the flask again, nearly, but not quite, to boiling.

The drop of nitric acid added before beginning the titration facilitates the precipitation and collection of the MnO_2 in case there is a small amount of organic matter present, which has the effect of producing a turbidity which renders difficult the determination of the end-reaction. One drop of the acid obviates this difficulty, but more than two or three drops does more harm than good, as it prolongs the reaction to such an extent as to make the process tedious and uncertain.

I prefer to get at the strength of the permanganate in the ordinary way, by standardizing it against iron wire. When its strength in terms of iron is multiplied by $\frac{55}{160}$, its strength in terms of manganese is given.

I have been unable to obtain commercial zinc oxide which, when treated as in the regular course of the analysis, does not use up permanganate. I have, accordingly, bought the commercial zinc-white, dissolved it in nitric acid, or hydrochloric acid, making a neutral solution, added bromine, filtered from precipitated MnO_2, and other impurities, and then precipitated the zinc oxide with ammonia, subsequently washing thoroughly by decantation with distilled water. The zinc oxide held in suspension is then kept in wide-mouth bottles for use.

Volhard gives figures which prove the accuracy of this method, as does Haswell. Their results show that it is as accurate for high as for low percentages of manganese.

I determined manganese by the acetate and phosphate method in a piece of steel, the mean of two closely agreeing results being 1.72 per cent. By Volhard's method I obtained from the same drillings 1.71, 1.69, 1.74. Closer agreement than this in repeated determinations may be obtained after a little practice with the method, as is shown by the following results obtained from one set of drillings: 2.13, 2.13, 2.15, 2.13, 2.15, 2.16, 2.15.

It is quite necessary that the carbonaceous matter in the solution of steel should be destroyed by heating while sulphuric acid fumes

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are given off, otherwise the results obtained will be too high; but the above method of treatment obviates this difficulty entirely.

As carried out in my laboratory the method requires about forty-five minutes for a complete determination. Correct results have been obtained by it in forty minutes; forty-five minutes, however, is ample time.

Silicon and manganese may sometimes be determined advantageously from the same sample of steel, the filtrate from the silica, before washing with hydrochloric acid, being used for the manganese determination.

THE USE OF HIGH EXPLOSIVES IN THE BLAST FURNACE.

BY T. F. WITHERBEE, PORT HENRY, N. Y.

In a paper read at the Lake Superior meeting, August, 1880, an account was given of the successful use of Rendrock and Monaky powder upon a scaffold and salamander in the furnace. On April 5th, 1881, the same trouble called for like treatment, which, though not so immediately successful, was on the whole more instructive than the first trial, and points, I trust, to a reasonably sure remedy for all such difficulties. Up to December 4th, 1880, foundry and mill iron were made from Old Bed and New Bed magnetite, and Kearney red hematite, when a return was made to Bessemer iron, from an inferior quality of New Bed ore as compared with that used during first blast. January 18th, 1881, New Bed, Chateaugay, and East-shaft, a newly-opened Bessemer deposit of Messrs. Witherbee, Sherman & Co., were first used, and continued up to February 13th, on a fuel charge of 80 per cent. anthracite and 20 per cent. coke, the product on the three ores being about 10 tons more per day than on New Bed alone.

From this time until March 11th all coal was used, and New Bed, Chateaugay, and East-shaft ores, up to February 22d, and from that date Chateaugay and New Bed, the product falling off $9\frac{6}{10}$ tons per day as a result of not using coke. It is fair, however, to state that the furnace was not in good condition during this period, being over-burdened, and the New Bed ore was, temporarily, uncommonly poor, for reasons of no particular interest here. It required to properly flux it at least 140 per cent. of limestone, and 101 per cent. was actually used. March 11th, all Chateaugay ore and 30

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per cent. coke were charged, with the effect of increasing the make 26 $\frac{7}{10}$ tons per day up to the time our trouble began.

Although the working had been very good during this short run of twenty-one days, some trouble was indicated on account of the peculiar behavior of the blast pressure, which went up as high as 14 or 15 pounds as a result of a stop of not more than five or ten minutes at casting, requiring hours of hard blowing to bring it down again; while, if no more than one or two minutes were lost, it would start off normal—say, 10 pounds. The following is a detailed account of the beginning and end of the trouble:

First Day.—At 5 A.M., Tuesday, April 5th, 9 beds (15 tons) of No. 2 iron were cast; after casting, black cinder melted fast until 9 A.M., when a slip occurred upon checking the blast to stop the cinder notch. All the gas was then turned on to the stoves. The usual 11 A.M. cast was not attempted, as the quality of the cinder indicated that no iron would be found. At 5 P.M. a cast was made of 12 beds (18 tons) of fair No. 3 and No. 4 iron. Tuesday night we got a hole through the tuyere breast between No. 1 and No. 2 tuyeres, and heaved out an immense amount of mushy stock—coal, lime, and sticky cinder.

Second Day.—Wednesday, April 6th. Took out south cinder arch and heaved out the same material; also worked out a large hole pointing a trifle upwards, clear past the centre of the crucible, and about level with the tuyeres at its inner end, in the best possible location to repeat the experiment of a heavy blast, as before described. The fact that the hole pointed upwards made tamping more difficult, so extra precautions were taken. A 5-inch pipe with an end welded in was packed into the hole with damp clay, and then cooled by a stream of water injected into it. The cartridge consisted of a piece of 3½-inch gas pipe, plugged with wood at each end, and loaded with 13 ordinary 1¼-inch Rendrock cartridges, with two lines of fuse and exploders leading out. This was shoved into the 5-inch pipe, tamped or sealed with a ball of clay and fired with all possible dispatch, as the 5-inch case was red-hot. It failed to explode, as also did a second one, and from this cause probably came all of our subsequent trouble. The powder was then tested and found worthless. During the night some improvement took place; good runs of cinder from the south cinder arch, and at least 75 tons of mushy stock blown out, until it was banked up as high as the tuyeres, half way around the stack, making a stop necessary to clean up. At this time we had four good tuyeres at work. Procured a case of 50 pounds of Atlas powder.

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Third Day.—Thursday, April 7th. Discovered hole burned in the bustle wind pipe, 12 inches wide by 48 inches long. This was mended by taking out the 9-inch brick lining until the pipe was sound (about 5 feet) and forcing a car-wheel into each end, luting with clay between the flange and brick lining; these were held apart by a 1½-inch bar, with a collar at one end and nut at the other. The space was filled in with loose bricks grouted up solid with cement. A cast-iron plate was also bolted up into the bottom to cover the burned holes. This operation took sixteen hours. Upon starting, three tuyeres were found open and the hearth solid at their level. Nothing could be tapped out, and iron soon began to seal up the tuyeres. In one hour after wind went on No. 3 blowpipe burned off, and upon shutting down to stop it, all the tuyeres were filled solid with white iron. Six hours drilling failed to open a single one.

Fourth Day.—Friday, April 8th. Got a small hole through No. 4 tuyere, but could not maintain it. Also put in a small leaky charcoal tuyere, marked No. 8 on the drawing (Fig. 1), close up under the mantel. This opened into live stock above the obstruction, but its cinder could not be tapped out. It, however, gave some gas for the stoves, and in that respect was of subsequent benefit. The north cinder arch was also taken out this day and a hole worked in back of it about 2 feet, not far enough to allow of much execution from an explosion. However, it was charged with 25 Atlas cartridges, the heaviest charge yet used. Before loading, a test was made to ascertain the danger, by putting a handful of powder into a dry pine box similar to the cartridge case to be used. It remained three minutes and a half in the hole before it ignited, showing that there was but little risk, especially as the real cartridge case was wet and coated over with blue clay. The explosion (at 5 P.M.) had but little effect on the salamander; blew off one tuyere plate and racked the casing outward a trifle. It disclosed a solid leathery red-hot mass, containing but little coal and much lime. Men were at once set to drilling to get a hole up through to live stock. By hard work and liberal use of powder some progress was made. At 12 midnight a hole was got through to No. 8 tuyere, and a good fall of cinder came away. Perhaps the greatest benefit derived from this tuyere was the encouragement it gave us at this particular time. It was tapped several times before morning, and strong hopes were entertained that it might be induced to cut down

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to No. 3 tuyere, which was taken out and much drilling done to get a hole through, but without success.

Fifth Day.—Saturday, April 9th. The drift or shaft up through the salamander had progressed so far that some dust and gas came through. No. 9 breast and bronze tuyere was put at work, hoping that sufficient wind would pass in to open it. Blast was kept on Nos. 8 and 9 until Monday morning, none going through the latter. Considerable cinder was got away from No. 8, and in the meantime it burned out and was replaced by another leaky one.

Seventh Day.—Monday, April 11th. No. 8 gradually failed during preceding night, and by morning could not be cleared of cinder. At 10 A.M. wind was taken off and work resumed on the shaft. A hole was finally worked in that would take a case of 8 cartridges, which blew a hole up through into clean dry coal, 2 feet square, 14 feet from the bottom and 7 feet above the tuyeres. No. 9 was reset and wind got on by 11.45. A break-out occurred at 12.15 P.M., and at 12.30 cinder began to run from south cinder arch—"forge" at first, but soon changing to "hot." More gas came through than was wanted. In two hours clean coal appeared at No. 9 tuyere. This tuyere was tapped out at the bottom of the north cinder arch.

Eighth Day.—Tuesday, April 12th. Nos. 4 and 5 tuyeres were drilled open. Previous to this the iron dam plates were taken down and a large cavity blasted out toward No. 6 tuyere, where mostly coal was found.

Ninth Day.—Wednesday, April 13th. No. 9 tuyere was taken out at noon and No. 6 put at work in its place; at 1 P.M. got wind into No. 1 tuyere; at 2 P.M., cast 3 beds of iron, the first in eight days; 3 P.M., reset dam plate and got wind into No. 4 and No. 5 tuyeres.

Tenth Day.—Thursday, April 14th. Put in cinder arches and opened No. 2 tuyere. No. 3 was opened many times, but did not remain permanently open until over two weeks had passed. The crucible was badly banked up on the side of Nos. 2 and 3, perhaps as a result of the work of No. 8 tuyere, which could only be drained by the hole first opened, showing a ridge between it and the opposite side. At this time the trouble was fairly over, and there only remained for us to resume the regular charges, which had been replaced by fuel and cinder only. A few rounds were charged, until the 13th, when three-fourths of the ore was put on and soon increased up to the usual weight.

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In similar cases where the crucible becomes solidly filled with a gummy mass, entirely shutting out the blast, it seems to me that the best treatment is: 1. To try the effect of a heavy explosion near enough to the centre of the furnace to make it possible to break a hole up through, or at least to disrupt the mass enough to permit the blast to pass through, which will soon melt it out. The reason I recommend this plan first is that its success depends almost wholly upon getting a hole properly located, and of course the sooner this is begun the more chances for accomplishing it. To be sure, raising the tuyeres will, once in a while, do as well, but that is often difficult, and sometimes impossible, owing to the construction of the furnace.

2. Should the first fail, or should it be impossible to get a hole in the proper location early enough, then there remains the slower, though probably surer, method of blasting up through to good fuel. This opinion is based upon the fact that such obstructions are seldom of any great thickness. Water casings, wrought-iron bosh-casings with extra tuyere holes, high mantels and thin walls ought to make the loss of a furnace of rare occurrence, as they would permit access to the obstruction in the shortest possible time. The plan of melting out with a blowpipe, successfully used at the Edgar Thomson works, is not overlooked, but its details are not known by the writer.

In loading holes overhead it was found sufficient simply to hold or prop the cartridge-box in the hole, usually by a ¼-inch iron rod serving as the handle, and dispense entirely with tamping. Small drills, say 1½ inch, work the best, and in case a large hole is required it is best to drill two or three close together and break out the core by firing light charges in one.

As to the danger to life or property, it may be dismissed as of no account, providing that the precautions indicated are always taken, and the loading done by a reasonably cool-headed person. In such trouble as that described, much depends upon the faithfulness and energy of the men, and I cannot too highly acknowledge the services of my two keepers, McDonald and Norton, especially the latter.

The blast at this furnace terminated July 2d, 1881; the materials were then shovelled out. Your attention is called to the drawing (Fig. 1), where the heavy solid line shows the lining when new, and the heavy irregular line its condition after three years and a half wear. In Vol. IV, p. 375, of the *Transactions*, I condemned the

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bell as too large, proof of which is shown by the destruction of the upper part of the lining, but the most conclusive evidence has been its general working.

In July, 1879, owing to a strike, this furnace chilled, and, in making repairs, the brickwork was only disturbed about 3 feet above and 3 feet below the tuyeres, as shown by the heavy dotted line at A. It will be noticed that it was necessary to "step out" the bricks under the tuyeres in order to get even 16 inches on the tuyere breasts, and that a quick return was made to meet the old brickwork, 16 inches thick in the bosh-casing, leaving quite an abrupt shoulder at the tuyeres.

In the hearth of 1878 alternate tuyeres were projected further in (Nos. 1, 3, and 5), *i. e.*, there were two tuyere circles, one of 6 feet and one of 7 feet 3 inches diameter. (See Fig. 2.) Upon hastily repairing in 1879 all long tuyeres were used, giving a 6-foot circle. Now, in view of what was found in cleaning out, I would like the opinion of our furnace members as to what error of construction was due the fact that the wood with which this furnace was filled remained on the boshes, as shown, two years! Was it too large a bell, giving rise to the formation of a "chimney," or too small a tuyere circle (6 feet) in 1879, or both? The lining was cut to its present size when using the tuyere plan of 1878 (7 feet 3 inches circle), which is about the diameter of the bell (7 feet 6 inches), and it would seem that the wood escaped mainly for the reason that the tuyeres projected too far in.

I may add that this bell worked better in a 16-foot bosh than in a 17, which I am inclined to think is reasonable to expect. This wood was placed around next to the lining, to protect it while filling with the bell, and was found as placed, in a vertical position, strongly compacted together, but by no means crushed. It was protected by a fine, dusty, carbonaceous covering (small coal and coke in part), and, as found, was not sealed up with cinder, though this had flowed over it at some time, as the cracks in the charcoal are often found filled with it. In thickness it was about 12 inches, located as shown on drawing. The bosh as formed by it and its covering was 35 feet from the bottom, at which point the bricks were first found bare. The material that passed through this wooden bosh amounted to 136,159 tons of coal, coke, ore, and stone, in two years, and the best work done by the furnace was during this period. The above would seem to indicate that boshes suffer less from abrasion than from fusion and chemical action.

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To complete the record, I append a

MEMORANDUM OF FILLING.

DATE.	Wood.	Charges.	Magnesian Limestone	Common Limestone.	Cinder.	Fine Ore.	Lump Ore.	Coal.	Coke.
Aug. 11th, 1879.....	14 Cords.*	8	.....	.....	.....	.....	.....	.....	300
Aug. 12th.....	.....	10	.....	.....	.....	.....	.....	.....	300
		5	156	78	750	.....	150	3000	150
		3	222	111	1500	.....	300	3000	150
		3	288	144	1500	.....	450	3000	150
		3	354	177	1500	.....	600	3000	150
		3	420	210	1500	.....	750	3000	150
		3	486	243	1500	.....	900	3000	150
		3	600	300	1500	.....	1200	3000	150
		3	688	344	1200	.....	1400	3000	150
		3	776	388	1200	.....	1600	3000	150
		2	864	432	1000	.....	1800	3000	150
Aug. 13th.....	.....	1	864	432	1000	.....	1800	3000	150
		4	952	476	900	.....	2000	3000	150
		3	1040	520	800	.....	2200	3000	150
		3	1128	564	700	.....	2400	3000	150
		3	1216	608	600	.....	2600	3000	150
		3	1304	652	500	.....	2800	3000	150
		3	1392	696	500	.....	3000	3000	150
		3	1448	724	500	200	3000	3000	150
		3	1504	752	500	400	3000	3000	150
		3	1560	780	500	600	3000	3000	150
		3	1616	808	500	800	3000	3000	150
		1	1672	836	500	1000	3000	3000	150
	full to hopper.								
Aug. 14th, fired at 2.21 P.M.									
Aug. 15th.....	.....	6	1672	836	.....	1000	3000	3000	150
Aug. 16th, put on blast at 10.40 A.M.; first cinder, 11 P.M.	.....	6	1728	836	.....	1200	3000	3000	150
		7	1784	864	.....	1400	3000	3000	150
		8	1840	920	.....	1600	3000	3000	150
Aug. 17th, first iron, 7.30 A.M.	.....	40	1840	920	.....	1600	3000	3000	150
		8	1896	948	.....	1800	3000	3000	150

* A layer of wood was placed next lining, 1½ to 2 feet thick, about half the height of furnac to protect the brickwork. The charges (except the wood) were dropped by the bell instead lowered by tubs, as usual. Iron made first day, 20 tons, mottled; iron made second day, 8 tons, N 2, 20½ tons, No. 3.

THE FLANNERY BOILER-SETTING FOR THE PREVENTION OF SMOKE.

BY CHAS. A. ASHBURNER, PHILADELPHIA.

THE appliances which have been proposed, and the modifications in the construction of boiler-furnaces which have been made for the prevention of smoke, and the utilization of what are ordinarily called the waste products of combustion, have been innumerable.†

† There is now open in London an exhibition "of apparatus of all kinds devised to prevent smoke."

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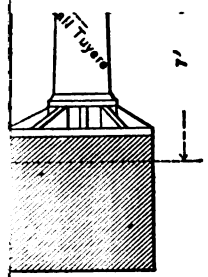

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The Flannery boiler-setting, which I wish briefly to describe to the members of the Institute, contains probably no one new original device; but it is rather a new combination of parts which, in its practical working, effectually prevents smoke from being thrown off from the chimney, and utilizes the heat units contained in the products generally lost. The quantity of fuel required to produce a given result is, in consequence, reduced.

As early as 1858 one hundred and three different plans of boiler-furnaces for the prevention of smoke were submitted at one time to the Steam Coal Collieries' Association, Newcastle-upon-Tyne. In a report upon these plans made by Messrs. Longridge, Armstrong, and Richardson, the furnaces were divided into seven distinct groups, according to the principles involved in their construction. The plans which have been proposed since 1858 have been, in most cases, more practical, more economical, and more efficient applications of the same principles.

The products of the combustion of bituminous coal, on a simple furnace fire-grate, are generally considered to be steam, carbonic acid, carbonic oxide, and soot. Of these, the first two are incombustible, the last two combustible. To these four products may be added the nitrogen of the air.

In cases, even, where the draft of air through the grate-bars is not excessive, there is a certain amount of unconsumed oxygen which passes through the boiler flues with the products of combustion. Absolutely perfect combustion of bituminous coal produces only steam and carbonic acid. The more nearly a furnace approaches this result, the more efficient it is in economizing fuel and in the prevention of smoke, or, more strictly speaking, soot, which is the solid carbon contained in smoke.

The economy of combustion in the Flannery furnace lies in the fact that the soot and carbonic oxide (which pass off through the chimney of an ordinary furnace) are almost entirely converted into carbonic acid before leaving the boiler flues. It is not my purpose to claim for this furnace the greatest economy of construction or duty, or even to make comparisons with other furnaces or boiler-settings which have been devised to accomplish the same end, but merely to describe a boiler-setting which, by experience, has been found to be practical and economical, and which seems to accomplish all that the designer claims for it. It is impossible for me to state in precise terms the value of the increase of heat obtained. As a rule, practical results differ so widely from theoretical computations

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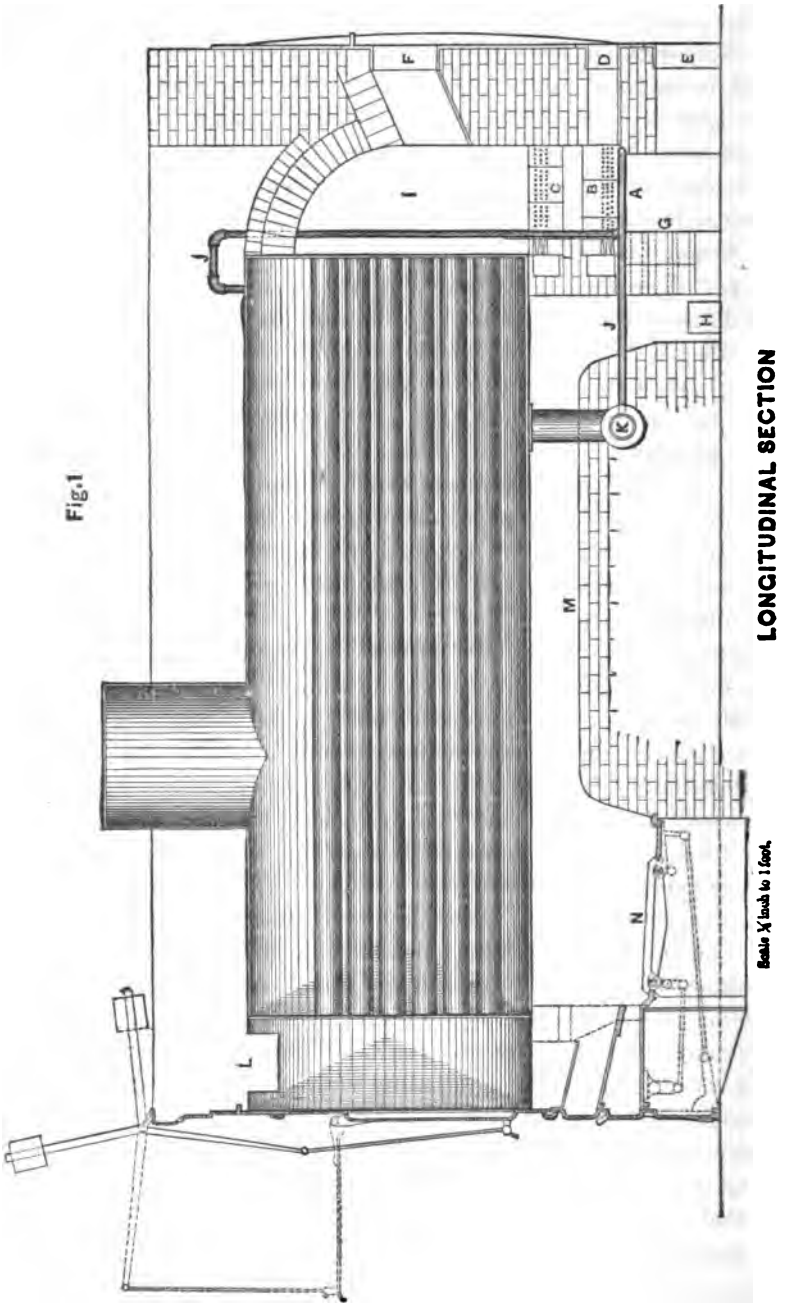
that they can best be made after the determination of empirical values. The most important results to be noted, where this furnace



is now in use, are: The total absence of smoke, though a dirty and

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highly bituminous coal is used; a total saving of about 33 per cent. of the coal required in an ordinary boiler-setting, with the use of the same boiler and engine; and a great saving in the labor required to keep the flues clean.

The front portion of the furnace may be constructed after any of the ordinary designs which are applicable to a plain cylinder, cylinder-flue, cylinder-tubular, or the other general forms of steam boilers in common use. The boiler which is illustrated by the accompanying drawings is an ordinary cylinder-tubular boiler which is being erected at Beloit, Wisconsin, for the Rock River Paper Company.

The most important points to be noted in this boiler are: The gas-flues at G (Fig. 1), where the temperature of the products is equalized; the secondary grate, A, with incandescent coals through which the products are passed, and the air-ducts, C, above this grate, where heated air is introduced, whereby combustion is completed in the chamber I.

After combustion has taken place at the front grate, N, the products resulting therefrom pass under the boiler and over the bridge-wall, M. At the rear end of what is called the combustion-flue, and a short distance (about 1 foot) back of the end of the boiler, the gases and soot are deflected by a firebrick wall downwards, and caused to pass through 25 circular flues in the lower part (Figs. 4 and 5). These flues are 3 inches in diameter, and 1 foot 3 inches long. In the furnace which has been working for some time at Akron, Ohio, there is but one large opening in this wall, but the substitution of a number of smaller flues is thought to be a decided improvement. The flues are cleaned when necessary from the ash-door, E; the ashes may be taken out from the door E, or, better, from the door H (Fig. 1), which is placed for this purpose. In practice the flues do not become coated with soot.

After going through these flues the products pass up through the water-grate A, which is covered with incandescent coal. The fuel here may consist of wood or anthracite coal, or, better still, coke. The grate is surrounded by a firebrick wall perforated by holes, B, which lead into an air-duct opening at the doors B′ (Fig. 2). This air-duct is only used in kindling, or when the fire on the secondary grate becomes dead. In cases where limestone water is only to be had, a tile grate is employed instead of a water grate (see Fig. 5). The latter is, however, adjustable, and can be readily replaced when the pipes become coated with lime or burnt. Immediately above

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the surface of the incandescent fuel there is a second air-duct, C, which is similar to the first, and which admits of the constant flux of air. The air is heated before entering the furnace by a

Fig. 3.

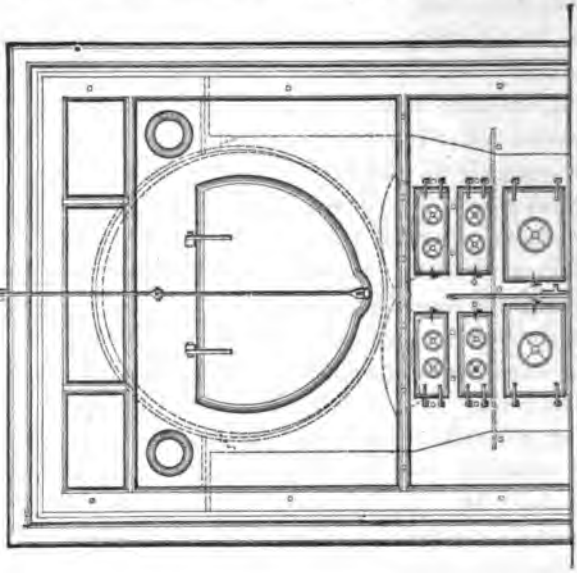
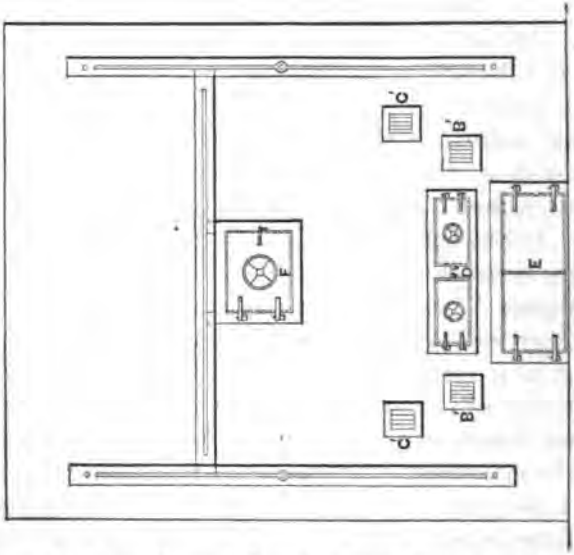


Fig. 2.



circulation around the wall confining the incandescent coals. T charging door for this grate is at F; I is the combustion-chamb

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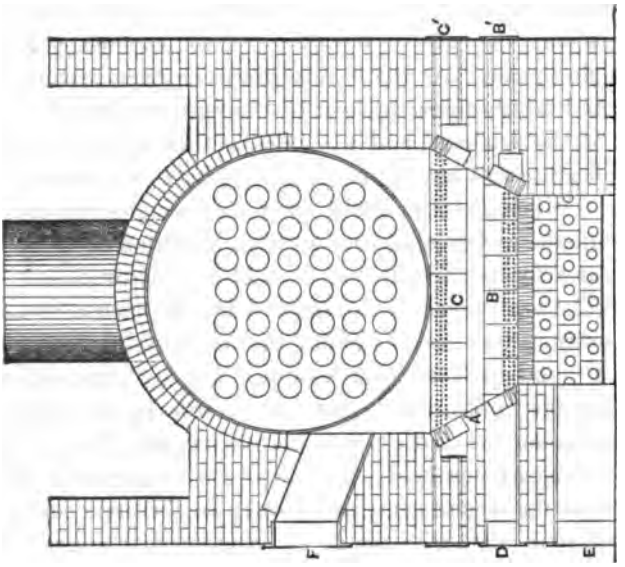
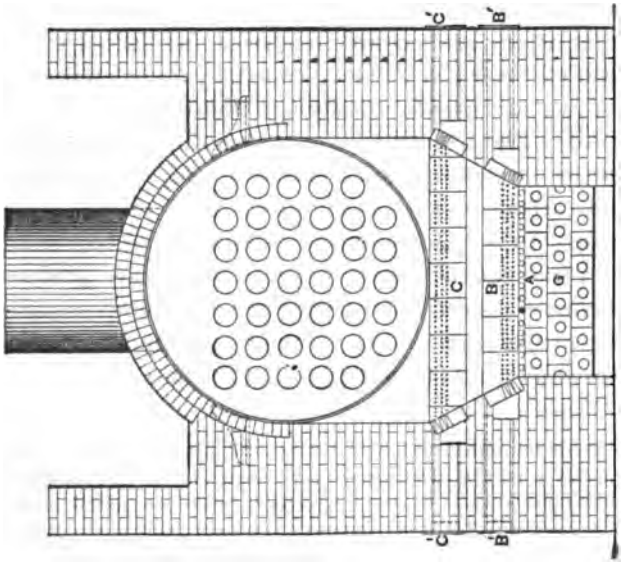
from which the ultimate products pass through the boiler-flues and are carried off by the chimney at the front end of the boiler.

Fig.3.



CROSS SECTION WITH TILE GRATE DOORS ON THE SIDE

Fig.4.



CROSS SECTION WITH WATER GRATE

The products of combustion which come from the front grate and enter the restoring flues, G, are a mixture of carbonic acid, carbonic

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oxide, air, soot, and steam.* In substituting a number of flues for one large one, a greater surface is gained, and the gases are more homogeneously heated. Of course these flues cannot give out any more heat than they absorb from the heated products as they come from the first grate. As the heat of these products is variable, due to firing and other causes, the heat of the flues will be an average of the heat of the products, and the gases as they enter the ash-pit of the second grate will have a more uniform heat than before entering the flues. When these products enter the incandescent coal on the second grate the carbonic acid unites with a portion of the carbon of the fuel and forms carbonic oxide. This is a direct loss of heat units.† The heat, however, is regained by the carbonic oxide thus formed uniting with the oxygen of the air introduced through the ducts C, C′, and carbonic acid results. The carbonic oxide which comes from the front grate is raised above the point of ignition by the incandescent fuel and unites with the oxygen of the introduced air and forms carbonic acid. The excess of atmospheric air enters the coals on the second grate and undergoes the same conversion as that which took place with the air entering the first grate. The particles of carbon, forming the soot from the first grate, are raised to incandescence and, uniting with the air from the ducts C, C′, form carbonic acid. The steam is decomposed in passing through the coals on the second grate, the oxygen uniting with the carbon forming carbonic oxide, which is afterwards converted into carbonic acid above the surface of the coals. The liberated hydrogen unites with the oxygen of the air introduced through the ducts C, C′, and again forms water. The ultimate products resulting from combustion in the Flannery furnace are, thus, carbonic acid, steam, and a small amount of carbonic oxide,‡ but no soot.

A number of the Flannery furnace-settings have been constructed, and after a trial extending over several months have produced more than anticipated results, in economizing fuel, in the consumption of soot and consequent prevention of smoke, and in a reduction in the labor, especially in that required to clean the flues.

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* Nitrogen is not considered, as it does not directly affect combustion.

† One pound of carbon in burning to carbonic acid gives out 14,500 heat units, one unit being the amount of heat required to raise one pound of water from 39° to 40° Fahrenheit. The same amount of carbon in burning to carbonic oxide gives out 4400 units.

‡ If the furnace is properly fired, and the draft properly regulated, all the carbonic oxide should be converted into carbonic acid in the combustion-chamber I.

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At the Akron water-works, recently constructed, two tubular boilers, 5 by 18 feet, with 64 4-inch flues each, have been set on the Flannery system. Two Worthington pumps have been erected, one a compound high pressure, the other a compound condensing. Up to the present time the high pressure pump and one boiler have alone been in service. The facts which have been noted in regard to the efficiency of the furnace have been very general, but they are such as to indicate its economy. The furnace has been fired day and night, for eleven days, with 14 tons of a dirty, bituminous slack coal, which is mined in the vicinity of Akron, and sold at the works for $1.00 per ton. On the second grate Connellsville coke has been used, costing $6.00 per ton. For every ton of coal burned 300 pounds of coke have been used, the coke costing $0.90 per ton of coal consumed. The total cost of fuel for eleven days was $26.60.

The reservoir attached to the works is 210 feet above the pumps, and 2700 feet distant. The consumption of water has been about 1,000,000 gallons a day. To do the same work the boiler with the usual setting would have required at least 35 tons of coal, at a cost of $35.00.

The average saving which would result in most cases from the use of the Flannery furnace, would undoubtedly be greater than that shown at Akron, where the coal used is very poor, and the cost exceptionally low. At Akron local conditions made it necessary to return the gases from the smoke-arch to the rear of the boiler where the chimney stands, through a flue 40 inches square and 27 feet long. This is considered to be a disadvantage. I am informed by the superintendent of the works that the labor required to run this boiler is one-half of that which is ordinarily required with the usual setting.

The advantages which are claimed for this boiler-setting are: Economy of fuel and prevention of smoke; economy of labor; more even action of the boiler and its longer continuance in service, due to the small amount of deposits in the flues.

The system is particularly applicable in the setting of boilers where continuous service is required, where the cost of fuel is great, where the space occupied by fuel is valuable, or where the production of smoke is objectionable.

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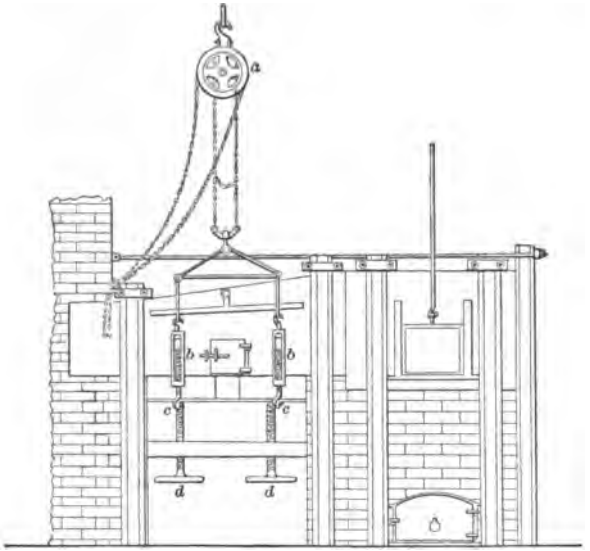
TEST SUPPORT FOR THE ENGLISH CUPELLATION FURNACE.

BY F. C. BLAKE, MANSFIELD VALLEY, PA.

THE test of the English cupellation furnace should be so supported that the cupeller can change readily the elevation of the test, and at the same time watch the litharge channel. It is also important to raise or lower either side, independently of the other, in case of uneven wear of the side walls or of the breast. If the refined silver is poured from the test, it is much better to control the lowering of the test from the front than to raise the back by screws or a lever. In order to enable the cupeller to manipulate the test with one hand, when the litharge is running, and to pour the refined



a Pulley Block
b Turn Bolts
c Support Bars
d Back Screws
e Test Plate

Fig.1.

Scale of Feet 0 1 2 3

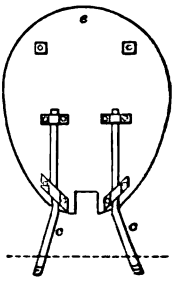


Fig.2.

silver from the test without aid, I have altered the common support to the test, as shown in the accompanying drawing.

The common method of supporting the test is by four screws, working in cross-bar nuts beneath the test. The points of the screws set into the test plate upon which the test rests. These screws are usually worked by pounding or pulling upon the heads, which may be either small pulleys or straight bars, as shown on the back screws in the drawing. The screws are also worked by turning a crank, which is

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connected by gearing to the heads of the screws. The test is sometimes supported upon wedges, but wedges are difficult to manage quickly if considerable change in elevation is to be made.

The altered form of support is shown in Fig. 1. Square bars are clamped to the under side of the test-plate, shown in Fig. 2. These bars extend a short distance in front of the furnace, and are bent outward, in order that the turn-bolts above may not interfere with the test front door. The back part of the test-plate rests, as usual, upon two screws. The front support-bars are connected by turn-bolts and a cross-piece to a Harrington pulley-block, hung from the girder above. It will be seen that the elevation of the front of the test can be readlily changed by the working of the pulley hand-chain, which can be easily done with one hand.

The turn-bolts, working with the back screws, allow a change to be made in the elevation of the sides. Ordinarily they are not often used. The front of the test can be lowered by the cupeller in front sufficiently to allow the test to run clean of silver or rich silver-lead without the use of a lever at the back. The principal advantages in this method of supporting are as follows:

1. The test can be raised or lowered quickly and evenly.
2. When changing the elevation of the front the cupeller can always watch the litharge channel.
3. The test is controlled from the front when silver or rich silver-lead is poured.

THE BINDING OF INWALLS OF BLAST FURNACES.

BY S. H. CHAUVENET, C.E., HARRISBURG, PA.

THE binding of the boshes and inwalls of blast furnaces has always been an expensive piece of work. When the old stone stack was replaced by the iron shell, the brickwork was kept at a thickness of five feet or more. These five-foot walls were still too thick, and the practice now is to have as thin walls as possible and to have a free circulation of air about the brickwork of the furnace. The "basket," or lattice-work binding, accomplishes this object, but it is expensive, as to first cost, and, if any change in the diameter of a furnace has to be made, it necessitates an alteration of the binding or of the thickness of the walls.

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In the year 1879 I had occasion to alter a furnace, built as shown in Fig. 1, to the shape shown in Fig. 2. The walls were reduced from sixty to thirty-two inches in thickness, leaving a space between the lower part of the inwall and the outside of the bosh. That part of the bosh below the mantle was bound with T rails; but, above the

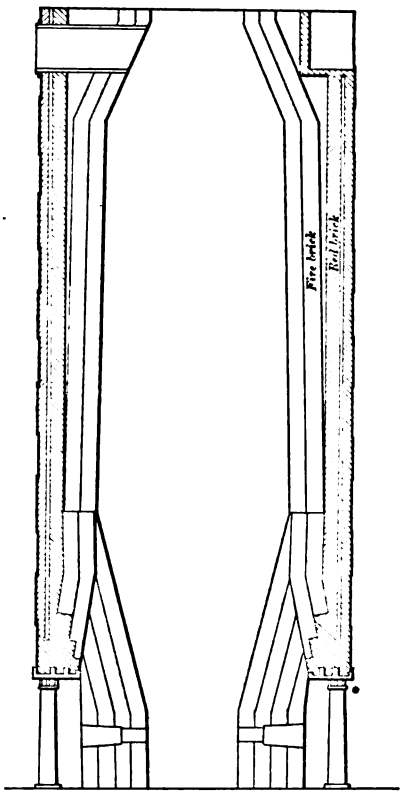

Fig. 1.

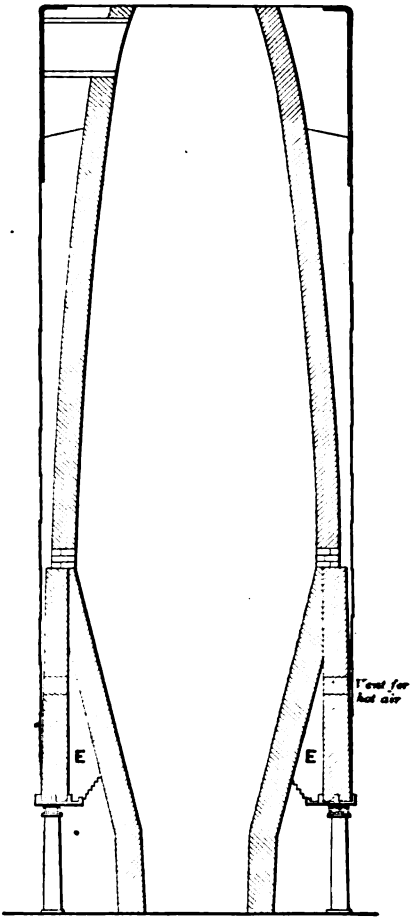

Fig. 2.

mantle, brick piers, E, E, were built, twelve inches in thickness and three or four feet apart,—similar to those shown in Fig. 4,—having the mantle for a base, and filling the space between the bosh and the inwall. The space between the shell and the inwall on this furnace was filled with broken blast-furnace slag. Of course this style of binding for the bosh would only be applicable to furnaces with low columns.

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A furnace with high columns and the inwall bound with brick piers is shown in Fig. 3. The piers are four and a half or five feet from centre to centre, as shown in the section C D, Fig. 4, and between each two piers a hole, twelve or eighteen inches in diameter, is

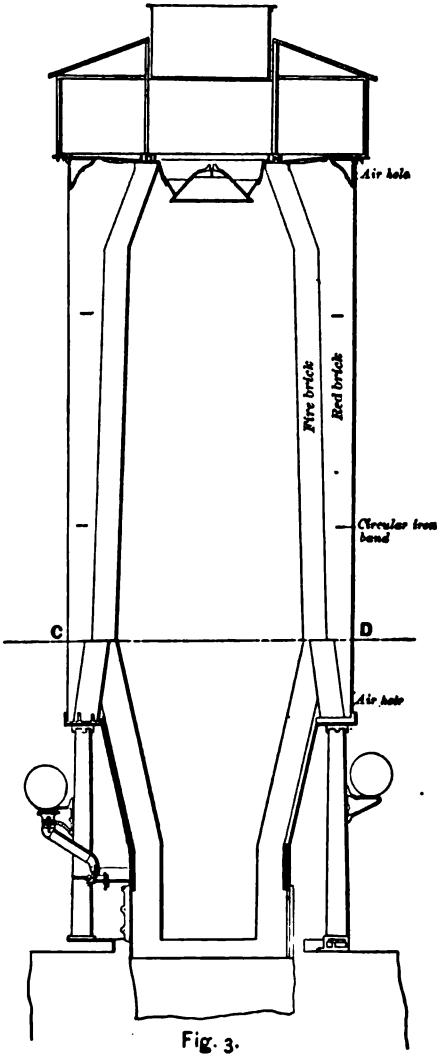

Fig. 3.

cut in the shell, just above the mantle. There is a corresponding hole just under the tunnel-head plates. This makes the space between the inwall and the shell a flue through which cold air is drawn. Any

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gas escaping through the brickwork is carried off, and, should a bad leak occur, a man can be lowered to it after the removal of one of the tunnel-head plates. The piers are built of red brick laid in

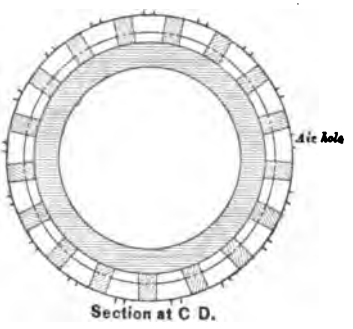

Fig 4.

mortar, and a space is left between the back of the pier and the shell for expansion, varying in width with the fire-brick used and the size of the furnace. The piers are stiffened laterally by circular iron bands built into them at two or three points.

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PROCEEDINGS

OF THE

ANNUAL MEETING, WASHINGTON, D. C.

FEBRUARY, 1882.

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LOCAL COMMITTEE OF ARRANGEMENTS.

Major J. W. Powell, *Chairman;* F. P. Dewey, *Secretary;* S. F. Emmons, A. S. Hewitt, J. E. Hilgard, Charles Knap, and F. W. Taylor.

THE opening session was held in the hall of the new National Museum, on Tuesday evening, February 21st. President Metcalf introduced General W. T. Sherman, one of the Regents of the Smithsonian Institution, who read the following address:

ADDRESS OF GENERAL SHERMAN.

MR. PRESIDENT AND GENTLEMEN: I have been invited to meet you here this evening to extend to you the cordial greeting of the regents of the Smithsonian Institution, and to assure you that they are most happy to have it in their power to place at your disposal this beautiful hall, dedicated to science and art.

This National Museum is the property of the United States, of which the regents of the Smithsonian are simply the custodians, and the board has delegated to its secretary, Professor Baird, the right to extend its use to the National Academy of Sciences and like kindred societies, among which we are glad to class the Institute of Mining Engineers. It is eminently fit that you should meet here at this, the nation's capital, under a roof partly your own, devoted to natural sciences, and in the shadow of the Smithsonian, founded for the exclusive purpose of collecting and diffusing knowledge among men.

Of all the workers employed on earth no single class seem to me more worthy the respect of their fellows than those who seek beneath the surface for the useful minerals and metals which contribute so largely to the wealth and comfort of mankind. In no branch of human industry does intelligence come so immediately in contact with labor. To the mining engineer chemistry, mineralogy, and geology are as reading, writing, and arithmetic to the merchant;

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and algebra, trigonometry, and geography to the navigator. There is no business or profession where ignorance is so fatal, or mistakes more disastrous. No single interest has done more to build up our present empire, and, in my opinion, on no other single interest except agriculture does the future grandeur and stability of our country more depend than on its mines and mineral wealth.

I do not mean to tire you with figures or statistics with which you are doubtless more familiar than I am, but I cannot refrain from giving a very few out of the great mass which have been selected by those engaged in compiling the late census of 1880.

ANTHRACITE COAL.

Product for year ending June 1st, 1880,	27,433,329 tons.
Value of product,	$40,331,981
Total capital, real and personal,	$150,161,196
Number of men employed above ground,	15,564
Number of men employed under ground,	36,952
Number of boys, under 16, above ground,	11,921
Number of boys, under 16, under ground,	3,802
Total employés,	68,239

BITUMINOUS COAL.

East of 100° *Meridian.*

Product for year ending June 1st, 1880,	40,311,459 tons.
Value of product delivered,	$49,044,498
Total capital, real and personal,	$89,999,101
Number of men employed above ground,	18,842
Number of men employed under ground,	76,512
Number of boys, under 16, above ground,	755
Number of boys, under 16, under ground,	5,366
Total employés,	96,475

West of 100° *Meridian.*

Product for year ending June 1st, 1880,	1,477,736 tons.
Value of product at mines,	$8,272,470
Total capital, real and personal,	$8,479,573
Number of men employed above ground,	621
Number of men employed under ground,	2,812
Number of boys employed above ground,	
Number of boys employed under ground,	8
Total employés,	3,441

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IRON ORE.

Product for year ending June 1st, 1880, . .	7,971,706 tons.
Value of product, ...	$23,167,007
Total capital, real and personal, . . .	$61,782,287
Men employed above ground, ...	16,345
Men employed under ground, ...	13,735
Boys, under 16, above ground, ...	1,339
Boys, under 16, under ground, ...	249
Total employés, ...	31,668

COPPER.

Product for year ending June 1st, 1880, . .	50,665,140 lbs.
Value of product, ...	$8,842,961
Total capital, real and personal, . . .	$31,675,096
Men employed above ground, ...	2,755
Men employed under ground, ...	3,069
Boys employed above ground, ...	202
Boys employed under ground, ...	90
Total employés, ...	6,116

Of copper, the Lake Superior region furnishes 90 per cent. of all, and yields pure copper enough to cover 25¼ acres with a sheet one inch thick.

The amount of gold produced in the census year 1880 was $33,379,663. The amount of silver is reported as $41,110,957, making the aggregate of the precious metals, used as coin the world over, $74,490,620.

These figures are official; they do not exaggerate, but fall short of the whole truth. They exhibit the net products of some of our mines. When we follow the metals in their development for the uses of civilized men, when we remember that it takes 2 tons of iron ore and from 2 to 2½ tons of coal to make a ton of pig-iron, worth from $20 to $26, that by further manipulation this same ton becomes worth $40 to $60 for railroads, from $60 to $100 for mechanical uses, from $2000 to $4000 a ton in the shape of needles, and that for watch-springs this value becomes $1,000,000, there is opened the question of manufactures not pertinent to this occasion; but you, the mining engineers, give the initiative to this most important subject, you delve into the earth and reach the fountain source of this stream of vital industry. I, myself, was in the New Almaden quicksilver mines of California as early as 1847, and saw the Indian

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miners with pick and crow-bar collect the beautiful mineral, load it into raw-hide sacks, pack it on their backs, and run like rats up notched poles to the mouth of the mine, whence it was hauled in ox-wagons to the furnaces in the valley below.

I saw the first specimens of gold found in Sutter's famous mill-race, and witnessed all the changes from the common tin-pan to the cradle, the long-tom, the hydraulics, the arrastre, and the hundred-stamp mill, roaring like the anvils of the Gods, with flumes 30 miles long, to bring the water needed to separate the metal from its matrix.

I have been down in the copper mines of Lake Superior, with their oscillating engines and inclined railways leading to the deepest pits, where the highest science and ingenuity of man have reduced the necessary labor to the minimum, and produced that beautiful and most useful metal at little over 16 cents a pound.

I have also seen Mr. Hill's reverberatory furnace at Blackhawk, Colorado, with its roaring flames under the hot blast, melting down rock to a fluid, the useless slag successively skimmed off till the precious metals remain below, and are drawn off into the comparatively small matte. This again is reduced to a fine black powder as unlike silver as a pot of lamp-black; yet chemical affinities draw out the pure crystals of beautiful silver, and a further process eliminates the gold, and leaves still a valuable residue of lead, copper, and iron.

I have been down in the deep mines of Nevada where the terrestrial heat suggests a hotter place; where steam-elevators bring up the mineral, and steam-pumps deliver an abundance of hot water to supply the rotaries; and I have seen coal and iron mines of every conceivable kind in all quarters of our country, so that I have had some experience, and can bear willing testimony to the industry, the skill, and ingenuity of our mining engineers everywhere.

The sinking of shafts, the running of galleries, the disposal of waste material, the guarding against water and rock-slides, the prevention of fatal gases, all combine to make your life a continual warfare with nature, and call for a courage equal to that of the soldier in battle; but as the soldier will follow his leader to the death when convinced of his skill, so will the miner penetrate the earth to its inmost recesses if convinced of the skill of his engineer. This is a great and sacred trust, for which you should be fully prepared by previous study, reflection, and experience. I am confident that you will prove equal to every change and emergency which may

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arise, and your meeting here is most auspicious, if by comparing your personal experiences you can make the occupation of the miner more safe and more profitable than it has heretofore been.

There is in the business world as much friction as in mechanics. A constant vital mental force is ever necessary to overcome old habits and methods to which the miner clings with as much tenacity as any other class. But we know that change is written in broad characters across the face of nature. True, to-day is as yesterday, and the coming spring will bring forth its flowers as in the past, but there was no steam-engine at the beginning of this century; the photograph and telegraph were unknown fifty years ago; within twenty years have been added to the stock of human knowledge the telephone and electric light, and these things are now as essential to human life as food and clothing. We know not what new inventions are yet to be, but we do know that the man who holds back too long and clings to the familiar knowledge of the past, refusing new knowledge, will be left behind in the great race of life. He will be as the passenger of the old stage-coach, left in a mud-hole, whilst his neighbor will be hurled along at the rate of 30 miles an hour in the modern steam-car. So the mining engineer must keep pace with the mechanical arts; must utilize every new and approved contrivance to diminish human labor and increase net profits, else he will lag behind and see his neighbor prosper. In Egypt you can find to-day the same old wells and pumps worked by camels and asses as were there in the days of Moses; and in Mexico you will find women down on their knees grinding corn with the matate, and the old arrastre going round and round with its mule; whilst in the most inaccessible corners of California, Nevada, and Arizona the cough of the steam-engine is heard, and the thunder of the stamp-mill shakes the earth. It is not for us to say which system produces the largest measure of human happiness. It suffices for us to know that we prefer the latter, and mean to reduce mining to an absolute science, yielding the largest profits, and increasing the comfort and safety of the miner to equal those of the farmer.

The Smithsonian accepts the past, and only deals with *new* knowledge,—the "increment,"—so that when you are down in the fissures of the earth and discover any new metal, mineral, or principle of natural law, we expect you to add your mite to that colossal column of human knowledge which towers high above the Pyramids of Egypt, and in return we will be most happy to reciprocate by supplying that which we gather from the uttermost parts of the earth. The

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Republic of Science has no earthly limits. It embraces the heavens above, the world below, and the waters under the earth;—so, my friends, we are a common brotherhood, and we trust that wisdom will govern your counsels, and that honor and success will crown your labors.

Major J. W. Powell, Director of the United States Geological Survey, and Chairman of the Local Committee of Arrangements, then spoke as follows:

ADDRESS OF MAJOR POWELL.

MR. PRESIDENT AND GENTLEMEN, MEMBERS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS: I bid you welcome. It is appropriate for me thus to greet you only because of my relation to the Geological Survey prosecuted under the direction of the General Government. The work in which my collaborators and myself are engaged is intimately related to that in which you are professionally employed.

Mining engineering must have a sound basis in structural geology, but the general structural geology of the country can only be discovered and delineated by the great agencies of government, and hence our own, alike with all civilized governments, is engaged in prosecuting this department of research.

But the Geological Survey is also engaged in researches in mining geology. In the past two or three years the Comstock lode, from which three hundred millions of bullion have been taken, has been the subject of most minute and careful examination by a corps of the Geological Survey. Another has been engaged in the examination of the Eureka mining district. Still another in that marvellous group of mines at Leadville, Colorado. Other corps have been engaged in the examination of the coal of the United States, of the iron mines, of the copper regions, and of the industries in the production of the precious metals.

The purpose of these researches is somewhat more general than that in which you are individually engaged. The Geological Survey seeks to discover:

First. The geological structure of the country.

Second. The geological relations and palingenesis of ores and other mineral deposits, and to discover the laws and modes of their occur-

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rence. Here the work of the official geologist ends, and here the work of the mining engineer begins. It is for him to develop individual mines and to discover the sites of ore-bodies and other valuable deposits, and to develop the machinery for the working of mines, and metallurgical processes by which crude materials may be wrought into forms best adapted to the wants of man. This gives rise to the profession of mining engineering. So the body of geologists and the body of mining engineers of the country are complementary to each other, and constitute one profession, and work to a common purpose,—the development of one of the most important groups of industries in the civilized world.

The successful mining engineer must be highly endowed. He must be a geologist, a mineralogist, a chemist, a metallurgist, a mechanician, and with all these, he must have that practical knowledge of the affairs of his profession that gives facility in the adaptation of means to ends. For no two mountains have the same structure, no two deposits have the same form, no two ores have the same constitution, no two mines present the same problems; and thus in the mining engineer knowledge and skill are alike demanded. With all of these must go professional pride and integrity, for the ardor of enthusiasts must be checked and the wiles of sharpers thwarted.

In this field nature has concealed her bounties that they may not be found by the fool. The uninstructed eye sees no gold in the rock, no silver in the ore, no iron in the mountain, no coal beneath the plain—only to the eye of science are these secrets revealed. In this field, when native products are discovered, the hand of ignorance cannot seize them; the fool cannot unlock the treasure box. Only the hand of science, armed with the powers that are harnessed with machinery, can bring them to our possession. In this field the native products when gathered cannot be utilized by the ignorant. The fool holds not the wand of transformation; but science turns the rock into gold, the ore into silver, the iron into engines, and the coal into power. In this field science and art go hand in hand.

It was, therefore, peculiarly fitting that the men engaged in this work, the scientific artisans, the mining engineers, should associate as a corporate body for the promotion of knowledge and the development of technology. Such is the purpose to be subserved by this organization. How well this purpose has hitherto been accomplished is known and attested.

Since the organization of the Society nine volumes of *Transactions*

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have been published. These volumes contain four hundred and thirty-four papers, which may be classified as follows:

1. Metallurgy of iron and steel, one hundred and ten papers.
2. Metallurgy of silver and silver mining, twenty-two papers.
3. On various metallurgical processes, fifty-one papers.
4. Gold and gold mining, seven papers.
5. Mining and mechanical engineering, thirty-two papers.
6. On the mining and smelting of copper, fifteen papers.
7. Chemistry and assaying, twenty-six papers.
8. Economic geology and mineralogy, thirty-three papers.
9. On coal mining and the geological relations of coal, forty papers.
10. On the natural occurrence and metallurgy of zinc, antimony, bismuth, lead, nickel, graphite, and tin, eleven papers.
11. Concerning salt, three papers.
12. On ore-deposits and the working of mines, nineteen papers.
13. Mining tools and machinery, twenty-six papers.
14. Miscellaneous papers and addresses, thirty-nine papers.

The list of the authors of these papers is a catalogue of illustrious names of scholars, eminent writers, and successful engineers. The whole constitutes a body of literature of which any scientific association of the world might well be proud.

Civilization was born when the ancient cities were built on the shores of the Mediterranean. Prior to that time mankind was organized in tribes. Since that time the nations have been organized.

In the passage of mankind from tribal to national society in the growth of modern civilized states, the most important element is the growth of corporations,—voluntary associations of men for specific purposes,—industrial, educational, and charitable. The evolution of these corporations is the most important chapter in the history of the institutions of the civilized world. Progress made by mankind, from the building of the pyramids for glory, to the mining of the Comstock lode for its three hundred millions of bullion, is due more to these institutions developed by voluntary associations of men than by the institutions of government. These voluntary associations have been the most potent agencies in the progress of mankind from the earliest to the latest civilization, and the sociologic philosopher who has to deal with the progress of society, finds that the people of to-day, in the most highly developed governments, are more influenced by voluntary corporations than by governments themselves.

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In the history of governments the drama presents an exciting plot where ambitious actors walk the stage, and governments with their legislatures, their rulers, their courts, their armies, and their navies, appear in rapid sequence before us, and the play is heroic and tragic.

In the history of corporations the parts are played by bodies of men voluntarily associating and working together. To make fields in the forests, to work mines in the mountains, to navigate rivers, and to sail the seas, and to spread commerce throughout the world—these agencies have been more potent in the civilization, and more potent in the culture of mankind, than all the agencies of government.

It is within the memory of the men before me that historians have come to understand that written history has been too much occupied with governments and armies and navies, and has neglected the major part of history,—the part affecting most the interests of mankind. There have sprung up in the last decade or two historians throughout the civilized world, who are rewriting history by tracing the development of institutions of culture and of civilization. Of all human institutions those relating to industries have been most efficacious, most beneficent. Technology has done more for mankind than sociology, institutions of art more than institutions of government.

If we begin in the early history of mankind at that time when only tribal governments were known, when the state, the whole body of a people organized under one government, was but a body of kindred, and trace mankind through forms of states, by changes of governments, until the modern states of civilization appearing as empires, kingdoms, and republics are established, and study carefully the history of these changes and the course of this progress, we discover that the theories of government are developed not by the eloquence of statesmen, not by the wisdom of rulers, not by the judgments of courts, so much as by the development of industries appearing in the mining operations, the manufacturing works, the commercial enterprises through which the relations of men have changed and society has advanced. By the force of civil institutions relating chiefly to industries mankind has made progress, and slowly but inexorably states have grown from savagery to civilization.

Again, technology has done more for mankind than philosophy. Philosophy has never grown through internal agencies; philosophy

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has grown only by the culture which proceeds from technology. Philosophy would to-day be soaring in the absurdities of mythology or wading through the mire of metaphysics but for science, which was born of technology. Philosophy *was* mythology with its thaumaturgics and poetry. Then philosophy *was* metaphysics, with indeterminate propositions and occult proof. Now philosophy is science, and there is no philosophy but science. Technology is the father of science, and science again is the father of technology. Arts give birth to sciences and sciences give birth to arts, and thus in alternating generations they multiply to bless mankind.

Again, gentlemen, I welcome you, as the representatives of science and art, to Washington and to the national halls of science and art.

President Metcalf, after replying, on behalf of the Institute, to the addresses of welcome of General Sherman and Major Powell, gave an outline of the comprehensive work of the Institute, and expressed the pleasure that the members had in meeting within the walls of the national headquarters of science,—the Smithsonian Institution.

The following persons proposed for members and associates of the Institute, and approved by the Council, were unanimously elected :*

MEMBERS.

Arthur V. Abbott,	Brooklyn, N. Y.
George J. Atkins,	Newburgh, O.
William L. Austin,	Charleston, Arizona.
James F. Beattie,	Connellsville, Pa.
A. P. Berlin,	Hazleton, Pa.
Abram Bruner,	Pittsburgh, Pa.
H. C. Burchard,	Washington, D. C.
Charles S. Burt,	Marquette, Mich.
Byron W. Cheever,	Ann Arbor, Mich.
Townsend V. Church,	Chicago, Ill.
James B. Converse,	McKeesport, Pa.
Walter G. Coolidge,	Chicago, Ill.
George H. Cornell,	Youngstown, O.
Edward Daniels,	Washington, D. C.
Asbury Derland,	Boiling Springs, Pa.
A. H. Emery,	New York City.
George W. Eustace,	Jersey City, N. J.
John H. Flagler,	New York City.
M. N. Forney,	New York City.
Henry Gannett,	Washington, D. C.

* This list includes those members and associates who were elected at the final session of the meeting on Friday morning.

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George W. Goetz,	Cleveland, O.
Stephen W. Goodyear,	Waterbury, Conn.
Henry O. Hoffmann,	Kansas City, Mo.
F. N. Hofstott,	Pittsburgh, Pa.
William S. Hutchinson,	Chicago, Ill.
W. R Hutton,	Baltimore, Md.
Isaac E. James,	Tombstone, Arizona.
Lieutenant D. D. Johnson,	Governor's Island, N. Y.
R. R. Jones,	Chicago, Ill.
Thomas M. King,	Pittsburgh, Pa.
Benjamin B. Lawrence,	Montezuma, Colo.
E. P. Lee,	Chicago, Ill.
Thomas H. Leggett,	Batopilas, Mexico.
Edward P. Leisenring,	Audenreid, Pa.
Stuart Lindsley,	Clifton, Arizona.
Herman Livingstone,	Catskill Station, N. Y.
William Main,	Brooklyn, N. Y.
A. Markham,	Markhamville, N. B. Canada.
Charles A. Marshall,	Johnstown, Pa.
James H. Mayo,	Brookline, Mass.
O. E. Michaelis,	Frankford, Philadelphia.
Philip W. Moen,	Worcester, Mass.
Wilhelm Molin,	Troy, N. Y.
George Murray,	Leadville, Colo.
Albert H. Nicholson,	Orinoco, Venezuela.
John H. Paddock,	St. Johnsbury, Vt.
Henry W. Parkhurst,	Bismarck, Dakota.
John M. Pearson,	Hudson, N. Y.
F. N. Pease,	Altoona, Pa.
John C. Peters,	Eureka, Nevada.
J. C. Porter,	Pittsburgh, Pa.
S. A. Richards,	Joliet, Ill.
Samuel M. Riley,	Ashland, Pa.
Denis M. Riordan,	Tucson, Arizona.
Kenneth Robertson,	Oxford, N. J.
George W. Sargeant,	New York City.
David O. Saylor,	Allentown, Pa.
C. H. Scharar,	Providence, Pa.
Walter B. Scott,	Tucson, Arizona.
Henry J. Seaman,	Catasauqua, Pa.
Henry H. Stambaugh,	Youngstown, O.
Frederick J. Stanton,	Cheyenne, Wyoming.
Charles P. Tasker,	Philadelphia.
William Thaw, Jr.,	Pittsburgh, Pa.
Abraham H. Vandling,	Scranton, Pa.
J. H. E. Waters,	Silverton, Colo.
Valentine W. Weaver,	Coplay, Pa.
Charles G. Weir,	Ontonagon, Mich.
J. S. Wentz,	Mauch Chunk, Pa.
E. L. Wiles,	Chicago, Ill.
Albert H. Wolfe,	Chicago, Ill.

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ASSOCIATES.

Francis I. Dominick,	Clintonville, N. Y.
H. L. R. Emmet,	New York City.
J. W. Farquhar,	Easton, Pa.
C. H. Gibson,	Freiberg, Saxony,
Thomas B. Kerr,	Pittsburgh, Pa.
Willet Rose,	Irwin, Colo.
Henry H. Sawyer,	East Hampton, Mass.
Walter H. Weed,	Brooklyn, N. Y.
G. Norman Williamson,	Irwin, Colo.
Charles A. Wittmack,	New York City.

The status of the following associates was changed to member: Charles P. Bleecker, Philip E. Chazal, Anton Fernekes, Clark Fisher, Howard V. Furman, Frederick R. Hutton, Wheaton B. Kunhardt, Joseph T. Monell, Kiugo Nambu, Willard Ide Pierce, Donald B. Toucey, Hermann T. Vulté.

The President appointed Messrs. G. W. Bramwell and W. S. Dwight as scrutineers to examine the ballots for officers of the Institute, and to report at a subsequent session.

After the adjournment of this session the members attended the reception of Major and Mrs. Powell, at their house, 910 M Street.

The second session was held on Wednesday morning, when the following papers were read:

A Process for Making Artificial Fuel from Anthracite and Bituminous Coal Dust, and the Applicability of the Process to the Solidification and Utilization of the Slacking Lignites of the West, by E. F. Loiseau, of Philadelphia.

Coals in Mexico, Santa Rosa District, by W. H. Adams, of Chicago, Ill.

The New Mill at Batopilas, State of Chihuahua, Mexico, by J. C. F. Randolph, of New York city.

Comparative Efficiency of Fans and Positive Blowers, by Henry M. Howe, of New York.

A New Ore-pulverizer, by C. Henry Roney, of Philadelphia.

The session on Wednesday afternoon was devoted to the memory of Alexander Lyman Holley, who died January 29th, 1882. Dr. R. W. Raymond, at the request of President Metcalf, presided at this memorial session. Remarks were made by Messrs. William Metcalf, R. W. Raymond, T. S. Hunt, A. S. Hewitt, W. P. Shinn, Ashbel Welch, E. D. Leavitt, Jr., C. E. Dutton, R. W. Hunt, T.

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Egleston, G. W. Maynard, T. C. Clarke, Martin Coryell, J. H. Ricketson, O. Chanute, J. F. Holloway, Charles Macdonald, and J. D. Weeks. The Secretary read cable dispatches from England, which had been received during the day, from E. P. Martin, E. Windsor Richards, C. P. Sandberg, G. J. Snelus, S. G. Thomas, and the Council of the Institution of Civil Engineers. Written communications and telegrams were received from P. Barnes, J. C. Bayles, A. Cosgriff, W. E. C. Coxe, W. R. Jones, W. F. Mattes, E. C. Pechin, R. P. Rothwell, M. V. Smith, J. C. Smock, and W. J. Taylor, which could not be read at length for lack of time; and it was announced that the printed report of this memorial session would include contributions from friends of Mr. Holley who did not have the opportunity of speaking at the session.

The following resolutions were adopted:

Resolved, That in the death of Alexander Lyman Holley, formerly President of the Institute, we mourn the departure, not only of a great inventor and engineer, pioneer in the applications of science, and benefactor of mankind, but also, and more keenly, of a true comrade and dear friend, the memory of whose strong and gentle spirit is indissolubly blended with the social history of this organization, as his genius, enthusiasm, and activity were potent factors in its professional success.

Resolved, That the chairman of this meeting be requested to deliver, on some suitable future occasion, an address, in commemoration of the life and life-work of Mr. Holley.

Resolved, That the Council of the Institute be requested to take into consideration the publication of a memorial volume, to contain the above-mentioned address, the proceedings of this meeting, and such other matter as may be deemed expedient.

Resolved, That we extend to the American Society of Civil Engineers, and to the American Society of Mechanical Engineers, our sympathy in this great loss, sustained by them as well as ourselves.

Resolved, That a committee of five be appointed to take charge, after consultation with the Council, and in co-operation with such similar committees as may be constituted by our two sister-societies, of the execution of the measures proposed in these resolutions, and to represent the American Institute of Mining Engineers in any further proceedings that may be taken for the same purpose.

Resolved, That a copy of these resolutions, together with the assurance of our profound sympathy, be transmitted by the Secretary to the family of Mr. Holley; and that copies be sent also to the secretaries of the American Society of Mechanical Engineers and the American Society of Civil Engineers.

[At the next session of the Institute, Dr. R. W. Raymond was appointed chairman of the committee, provided for by these resolutions, with power to name the other members of the committee.]

At the conclusion of the session Dr. Raymond read a letter which he had received from Mr. Holley in the year 1876, and also a letter

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addressed to him by Mrs. Holley, desiring him to express her thanks to the members of the Institute for their kind expressions of sympathy, and to say to them how deeply Mr. Holley had been interested in the work of the Institute, and with what brotherly affection he had always regarded its members.

The fourth session, on Wednesday evening, was confined to papers and remarks on "Iron and Steel as Structural Materials," with especial reference to the memorial to Congress of the American Society of Civil Engineers for the appointment of a test commission.

The following persons took part in the discussion: Ashbel Welch, Charles Macdonald, General Meigs, Captain Lyle, E. D. Leavitt, Jr., T. C. Clarke, O. Chanute, A. P. Boller, T. Egleston, G. S. Morison, P. Roberts, Jr., and William Metcalf.

The fifth session was held on Thursday morning, Vice-President Thompson presiding.

The following papers were read:

First Aid to the Injured, by Professor H. S. Munroe, of New York city.

Electrical Apparatus and Processes for the Mining and Metallurgical Engineer, by N. S. Keith, of New York city.

Notes on some Newly Discovered Mineral Regions of Southern New Mexico, by Professor B. Silliman, of New Haven, Conn.

On Thursday afternoon the members, and accompanying ladies, visited the White House, and were received by President Arthur, and subsequently visited the Treasury Department, where they were received by Secretary Folger and shown over the treasury building.

On Thursday evening there was a subscription dinner at Wormley's Hotel.

The sixth and final session was held on Friday morning.

The following papers were read:

Late Developments in the Siemens Direct Process, by G. W. Maynard, of New York city.

Some Peculiarities of the Gold Deposits of North Carolina and the Bald Mountain Volcano, so-called, by Professor W. C. Kerr, of Raleigh, N. C.

Notes on the Behavior of Manganese to Carbon, by Willard P. Ward, of Savannah, Georgia.

The following papers were then read by title:

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The Southern Soapstones, Kaolin, and Fire-clays, and their Uses, by Professor P. H. Mell, Jr., of Auburn, Ala.

The Amount of Oil remaining in Pennsylvania and New York, by H. E. Wrigley, of Philadelphia.

Notes on the Luermann Front, by George Asmus, of New York city.

The Crystalline Rocks of Virginia compared with those of New England, by Professor C. H. Hitchcock, of Hanover, N. H.

Contributions to the Metallurgy of Nickel and of Copper, by W. E. C. Eustis and Henry M. Howe, of Boston.

Some Drift Deposits of Fossiliferous Hematites in Tennessee, by Edward Nichols, of Ridge Valley, Ga.

Phosphorus Determinations in Pig Iron and Steel, by F. E. Bachman, South St. Louis, Mo.

Instruments for Projection Drawing, by Professor J. M. Silliman, of Easton, Pa.

The Gold Fields of the Southern Portion of the Island of San Domingo, by R. P. Rothwell, of New York city.

Notes on the Large Blasts at the Glendon Limestone Quarry, by Frank Firmstone, of Easton, Pa.

Hoefer's Method of Studying Faults in Veins, by R. W. Raymond, of New York city.

The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota, by W. B. Devereux, of Globe, Arizona.

Valuation of Iron Mines in New York and New Jersey, by Professor J. C. Smock, of New Brunswick, N. J.

On Chimney Draught, by Professor B. W. Frazier, of Bethlehem, Pa.

A Review of the Ste. Genevieve Copper Deposit, by Frank Nicholson, of Ste. Genevieve, Mo.

Topographical and Geological Modelling, by O. B. Harden, of Philadelphia.

Note on Manganese in Bessemer Rail Steel, by J. W. Cabot, of Johnstown, Pa.

The Geology and Veins of Tombstone, Arizona, by W. P. Blake, of New Haven, Conn.

The Mining Work of the United States Geological Survey, by S. F. Emmons, of Washington, D. C.

Supplement III to a Catalogue of Official Reports upon Geological Surveys of the United States and Territories and of British North America, by Frederick Prime, Jr., of Philadelphia.

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The annual report of the Council was then read by the Secretary:

The Council, in accordance with the rules, reports to the members that the affairs of the Institute are in a highly satisfactory condition. The receipts for the year have been fortunately large, which has enabled us both to fund the life-memberships, and to meet the unusually heavy expenses of publication. The financial accounts of the Secretary and Treasurer, duly audited, show the following receipts and expenditures for the year:

SECRETARY AND TREASURER'S STATEMENT OF RECEIPTS AND DISBURSEMENTS FROM FEBRUARY 1ST, 1881, TO JANUARY 31ST, 1882.

DR.

Balance at last statement,	$1054 20	
Received for dues from members and associates,	8568 00	
" " life-memberships,	500 00	
" from sale of publications,	926 25	
" for binding *Transactions*,	272 50	
" " authors' pamphlets,	306 90	
" " electrotypes,	61 45	
Interest on United States bonds,	27 00	
" " deposits,	46 05	
		$11,762 35

CR.

Paid for printing volume ix, *Transactions*,	$2060 31	
" binding " "	600 50	
" printing pamphlet edition of papers,	1858 71	
" " " on Steel Rails,	147 50	
" " Glossary of Mining and Metallurgical Terms,	133 00	
Paid for printing circulars, etc.,	117 40	
" binding *Transactions* and exchanges,	171 38	
" drawing and engraving,	1028 55	
" lithographing,	277 75	
" postage,	745 67	
" freight and expressage,	223 13	
" stationery,	46 02	
" telegrams,	21 80	
" insurance,	47 50	
" stenographer,	25 00	
" rent of office, 6 months,	60 00	
" rent (storage of *Transactions*), 6 months,	25 00	
" Secretary's salary,	2000 00	
" " assistant's salary,	712 50	
" " and assistant's expenses attending meetings,	148 86	
Paid for incidental expenses of meetings,	82 88	
" 900 United States 4's,	1010 25	
		$11,543 71
Excess of receipts over expenditures,		$218 64

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The ninth volume of *Transactions*, covering the period from May, 1880, to February, 1881, has been issued and distributed as usual. It has not hitherto been found possible to issue these annual volumes more promptly, owing to tardiness of the authors in writing or revising their papers. This necessary delay, is, however, of no great loss to the members, since the pamphlet edition "subject to revision" gives a reasonably prompt publication of the papers read before the Institute. In addition to the regular publication of the papers, there have been issued in book form, an edition of the papers on Steel Rails, by Messrs. Sandberg, Dudley, and Holley, with the Discussions at the Philadelphia and Virginia meetings, and also a separate edition of Raymond's *Glossary of Mining and Metallurgical Terms*.

The usual three meetings have been held—in Philadelphia, Staunton, Va., and Harrisburg, Pa. These meetings were largely attended, and were highly successful, both professionally and socially. There were elected at these meetings 208 members and 48 associates. During the year 5 members have resigned, and 25 members and associates have been dropped from the rolls for the non-payment of dues. Eight members have died: J. R. Cameron, Henry Chisholm, Henry G. Clark, Maurice Healy, J. L. Jernegan, William Lorenz, Jr., Dr. A. Wendel, and Alexander L. Holley. The membership of the Institute now comprises 6 honorary members, 848 members, 125 associates, and 51 foreign members; a total of 1030.

The following resolutions, submitted to the Institute by the Council, were adopted:

WHEREAS, The American Institute of Mining Engineers, on the twenty-sixth day of March, 1879, leased for the term of ninety-nine years, to the Pennsylvania Museum and School of Industrial Art, in Philadelphia, the mining and metallurgical collections of the Institute derived from the Centennial Exhibition, and

WHEREAS, The Pennsylvania Museum and School of Industrial Art has suggested to the Institute, that the educational value of the above-mentioned collections would be increased if they were transferred to the National Museum in Washington, therefore

Resolved, That the American Institute of Mining Engineers consents to the breaking of the lease to the Pennsylvania Museum and School of Industrial Art, if desired by the latter, on condition that the collections of the Institute be transferred in their entirety to the National Museum in Washington; and

Resolved, That a committee of three members of the Institute be appointed by the President of the Institute to take all necessary action in this matter.

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In accordance with these resolutions, President Metcalf appointed, as committee, Messrs. P. Roberts, Jr., H. S. Drinker, and William G. Neilson.

The scrutineers appointed at the first session of the Institute presented their report, declaring the following persons elected as officers of the Institute:

PRESIDENT.

RICHARD P. ROTHWELL, ...	New York City.

VICE-PRESIDENTS.

(To serve until February, 1884.)

T. N. ELY, ...	Altoona, Pa.
CHARLES MACDONALD, ...	New York City.
MAJOR J. W. POWELL, ...	Washington, D. C.

MANAGERS.

(To serve until February, 1885.)

WILLIAM BURNHAM, ...	Philadelphia.
ANTON EILERS, ...	Denver, Col.
A. S. MCCREATH, ...	Harrisburg, Pa.

TREASURER

THEODORE D. RAND, ...	Philadelphia.

SECRETARY.

THOMAS M DROWN, ...	Easton, Pa.

The following resolutions were then offered and unanimously adopted:

Resolved, That the Secretary of the Institute be instructed to express the thanks of the members to Professor S. F. Baird, Secretary, and to the Regents of the Smithsonian Institution, for their kindness in offering the hall in the National Museum for the sessions of the Institute; to General Sherman, for his address to the Institute; to Major and Mrs. Powell, for their generous hospitality on the occasion of their reception to the visiting members and ladies; to the Cosmos Club of Washington, for their courtesy in extending to the members the privileges of the club; and to the efficient Local Committee of Arrangements, for their painstaking efforts to promote the success of the meeting.

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Resolved, That we tender our thanks to the retiring President, Mr. William Metcalf, for the faithful discharge of his official duties during the past year, and for the genial courtesy he has always shown in the management of our affairs; and we trust he will always remember his official connection with the Institute with as much pleasure as it will give the members to remember the meetings at which he presided.

President Metcalf responded briefly to the latter resolution, and then declared the meeting adjourned.

After the adjournment of this session the members visited the Bureau of Printing and Engraving.

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PAPERS

OF THE

ANNUAL MEETING.

FEBRUARY, 1882.

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ON CHIMNEY DRAUGHT.

BY PROFESSOR B. W. FRAZIER, LEHIGH UNIVERSITY, BETHLEHEM, PA.

I PROPOSE in this paper to treat of the chimney merely as a heat engine, as one of the devices resorted to in practice for the conversion of heat into mechanical work. For the sake of simplicity and clearness in the discussion, let us consider the subject in its simplest form.

Conceive a chamber, heated from without, in free communication at one end with the external atmosphere, and at the other end opening into a vertical chimney. Let the cross-section of the chamber be so great, relatively to that of the chimney, that we can neglect the actual energy of the air passing through the chamber. We will neglect, also, all passive resistances to the passage of the air. We will assume that the cross-section of the chimney is constant, and that the air in passing through it neither gains nor loses heat.

The following symbols will be employed in the discussion:

p_0 = the normal pressure of the atmosphere, which, it is assumed, is the pressure existing at the level of the chamber. $p_0 = 10332.96$ kilograms per square meter.

p_2 = the pressure of the external atmosphere at the top of the chimney.

T_0 = the absolute temperature of melting ice by the centigrade scale. This is assumed to be the temperature of the external air at the level of the chamber. $T_0 = 273°$.

T_2 = the absolute temperature of the air as it passes from the chamber to the chimney.

T_3 = the absolute temperature of the air as it issues from the chimney.

t_0, t_2, t_3 are the temperatures, as recorded on the centigrade thermometer, corresponding to the absolute temperatures T_0, T_2, T_3 respectively. $t_0 = 0°$ C.

In general, $t = T - 273$.

I_0, I_2, I_3 represent the intrinsic energy of the air at the temperatures T_0, T_2, T_3 respectively.

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v_0, v_2, v_3 represent the volumes of one kilogram of air at the following pressures and temperatures, viz.:

For v_0, p_0 and T_0,
For v_2, p_0 and T_2,
For v_3, p_2 and T_3.

δ represents the weight of one cubic meter of air at some pressure, p, and temperature, T.

In general $\delta = \frac{1}{v}$. Thus, $\delta_0 = \frac{1}{v_0}$, $\delta_2 = \frac{1}{v_2}$, $\delta_3 = \frac{1}{v_3}$. $\delta_0 = 1.29318$ kilograms.

γ = the ratio between the specific heat of air at constant pressure and that at constant volume. $\gamma = 1.408$.

S_p = the specific heat of air at constant pressure. $S_p = 0.2375$.

H = the height of the chimney in meters.

u = the velocity of the issuing air in meters per second.

E = the actual energy of the issuing air.

Let us follow the changes which the air undergoes. As it enters the chamber, the air has an intrinsic energy (I_0), corresponding to its temperature (T_0). We have assumed its actual energy to be so small that we can neglect it. A work of propulsion (W_p) is performed upon it by the external atmospheric pressure. The air is heated within the chamber to the temperature T_2, its intrinsic energy being thus increased to I_2; at the same time a work of dilatation (W_d) is performed upon it, which, according to our assumption, takes place at the constant pressure p_0. In passing up the chimney, the pressure of the air is reduced from p_0 to p_2. It consequently expands, and, as we have assumed that in the chimney no heat is either gained or lost, its temperature is reduced to T_3 and its intrinsic energy to I_3. In its ascent it overcomes the resistance of gravity, thus performing the work (W_g) of lifting itself through the height of the chimney. As it issues from the chimney it overcomes the back pressure (p_2), performing an amount of work which we shall designate W_b. It finally leaves the chimney possessed of the intrinsic energy I_3 and the actual energy E. By adding together on one side of an equation the quantities of energy brought in by the air and communicated to it from external sources, and of work performed on it by favoring external forces, and on the other side the quantities of energy carried off by the air, and of work performed by it against opposing external forces, we shall obtain an equation from which we can get an expres-

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sion for the actual energy of the issuing air. We thus get the equation:

$$I_0 + W_p + (I_2 - I_0) + W_d = W_g + W_b + I_3 + E. \quad (1.)$$

In this equation the terms $(I_2 - I_0) + W_d$ represent the energy communicated to the air in the shape of heat, which is absorbed partly in increasing its intrinsic energy, partly in performing the work of dilatation.

The following are the expressions for the intrinsic energy of the air:

$$I_0 = \frac{p_0 v_0}{\gamma - 1}, \quad I_2 = \frac{p_0 v_0}{\gamma - 1}\frac{T_2}{T_0}, \quad I_3 = \frac{p_0 v_0}{\gamma - 1}\frac{T_3}{T_0}.$$

The expressions for the different quantities of work and of actual energy are easily obtained under the assumptions which we have made:

$$W_p = p_0 v_0.$$
$$W_d = p_0 (v_2 - v_0).$$
$$W_g = H.$$
$$W_b = p_2 v_3.$$
$$E = \frac{u_1^2}{2g}.$$

The relations between the pressure, volume, and temperature of the air are given by the following equations:

$$\frac{p_0 v_0}{T_0} = \frac{p_0 v_2}{T_2} = \frac{p_2 v_3}{T_3}.$$

From these equations we get:

$$p_0 (v_2 - v_0) = p_0 v_0 \frac{T_2 - T_0}{T_0}.$$
$$p_2 v_3 = p_0 v_0 \frac{T_3}{T_0}.$$

Substituting these values for the terms in equation (1), we get:

$$\frac{p_0 v_0}{\gamma - 1} + p_0 v_0 + \frac{p_0 v_0}{\gamma - 1}\frac{T_2 - T_0}{T_0} + p_0 v_0 \frac{T_2 - T_0}{T_0}$$
$$= H + p_0 v_0 \frac{T_2}{T_0} + \frac{p_0 v_0}{\gamma - 1}\frac{T_3}{T_0} + E.$$

Solving this with reference to E, cancelling, and arranging, we get:

$$E = \frac{\gamma}{\gamma - 1} p_0 v_0 \frac{T_2 - T_3}{T_0} - H = \frac{\gamma}{\gamma - 1} p_0 v_0 \frac{T_2}{T_0}\frac{T_2 - T_3}{T_2} - H.$$

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As the expansion of the air from p_0 to p_2 takes place without gain or loss of heat, we have:

$$p_0 v_2^{\gamma} = p_2 v_2^{\gamma},$$

$$\frac{T_2}{T_2} = \left(\frac{v_2}{v_2}\right)^{\gamma-1} = \left(\frac{p_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}},$$

$$\frac{T_2 - T_2}{T_2} = \left(1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right),$$

Consequently

$$E = \frac{\gamma}{\gamma-1} p_0 v_0 \frac{T}{T_0} \left\{1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right\} - H. \qquad (2.)$$

In order to get an expression for H in terms of the volume and pressure of the air, let us assume that the change of pressure in the external air, between the top and the base of the chimney, is effected without gain or loss of heat. The variation in the pressure of the air, corresponding to an infinitely small increment of the height above the surface, is given by the equation:

$$\delta\, dh = -dp.$$

But, according to our assumption,

$$\delta = \delta_0 \left(\frac{p}{p_0}\right)^{\frac{1}{\gamma}} = \frac{1}{v_0} \left(\frac{p}{p_0}\right)^{\frac{1}{\gamma}}.$$

Substituting this value for δ in the preceding equation, we get:

$$dh = -p_0^{\frac{1}{\gamma}} v_0 \frac{dp}{p^{\frac{1}{\gamma}}}.$$

Integrating between the limits o and H for h, p_0 and p_2 for p, we get:

$$\int_0^H dh = p_0^{\frac{1}{\gamma}} v_0 \int_{p_0}^{p_2} -p^{-\frac{1}{\gamma}} dp.$$

$$H = \frac{\gamma}{\gamma-1} p_0^{\frac{1}{\gamma}} v_0 \left\{p_0^{\frac{\gamma-1}{\gamma}} - p_2^{\frac{\gamma-1}{\gamma}}\right\} = \frac{\gamma}{\gamma-1} p_0 v_0 \left\{1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right\}.$$

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Substituting this value for H in equation (2), we get:

$$E = \frac{\gamma}{\gamma - 1} p_0 v_0 \left\{ 1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma - 1}{\gamma}} \right\} \frac{T_2 - T_0}{T_0}, \qquad (3.)$$

Or

$$E = \frac{u^2}{2g} = H \frac{T_2 - T_0}{T_0}. \qquad (4.)$$

If one kilogram of air at T_0 were allowed to pass from the pressure p_0 to the pressure p_2, expanding without gain or loss of heat, its temperature would be reduced to T_1, and it would suffer a loss of intrinsic energy $(I_0 - I_1)$, which would be equal to the work of expansion (W_e), and this work would be entirely absorbed in increasing the actual energy of the air. An expression for the actual energy of the issuing air, under these circumstances, could be obtained by adding to the work of expansion the work of propulsion of the atmosphere, and subtracting from their sum the work of the back pressure. Thus:

$$E_0 = W'_p + W_e - W'_b.$$

But

$$W'_p = W_p = p_0 v_0,$$

$$W'_b = p_2 v_1 = p_0 v_0 \frac{T_1}{T_0} = p_0 v_0 \left(\frac{p_2}{p_0}\right)^{\frac{\gamma - 1}{\gamma}},$$

$$W_e = I_0 - I_1 = \frac{p_0 v_0}{\gamma - 1} \frac{T_0 - T_1}{T_0} = \frac{p_0 v_0}{\gamma - 1} \left\{ 1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma - 1}{\gamma}} \right\}.$$

Making the necessary substitutions and arranging, we obtain:

$$E_0 = \frac{\gamma}{\gamma - 1} p_0 v_0 \left\{ 1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma - 1}{\gamma}} \right\} = H. \qquad (5.)$$

The work of lifting one kilogram of air through the height of the chimney is equal to the actual energy which the same weight of air would acquire in passing without gain or loss of heat from the pressure p_0, at the temperature T_0, to the pressure p_2. As the difference in pressure between the base and the top of the chimney is due wholly to the action of gravity, the conclusion, just stated, is one which we might have expected. It may be expressed in other words by saying that the work of gravity outside of the chimney, in the descending current of cold air which restores the equilibrium destroyed by the draught of the chimney, is equal to the work of

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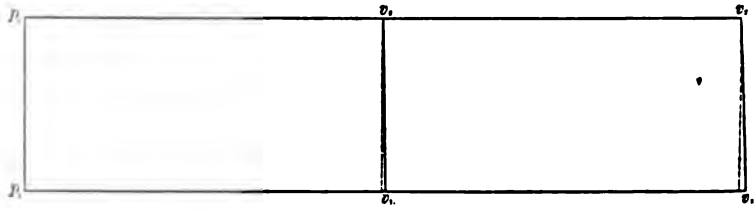
gravity overcome by the heated current of air rising within the chimney.

It is evident from the foregoing that the actual energy of the hot air issuing from the chimney is derived wholly from the heat imparted to the air, and that its amount relatively to the work of gravity is expressed by the fraction $\frac{T_2 - T_0}{T_0}$, a fraction which may have values greater or less than unity, as T_2 is greater or less than $2T_0$.

The analogy is evident between these results and those obtained in a previous discussion of the work performed in heating the blast.* The balance of work favoring the movement of the air (neglecting the work of gravity), if cold air were made to pass up the chimney, is analogous to the work of the blowing-engine. The actual energy which the cold air would possess, under these circumstances, in leaving the chimney is analogous to the actual energy of the jets of cold blast. In the chimney, however, this energy is completely absorbed in overcoming the adverse work of gravity, while in the case of the hot blast it remains intact, to be increased by the actual energy



transformed from heat. In both cases the expression for the amount of actual energy derived from the heating of the air is the same. In the case of the chimney this constitutes all of the actual energy of the issuing air, while in the hot-blast oven it adds itself to the actual energy communicated by the blowing-engine. The analogy is apparent, also, in the accompanying diagram representing the changes in the pressure and volume of the air. It is evident that the work of gravity, like the work of the blowing-engine, is represented by the area $p_0\, v_0\, v_1\, p_2$ (corresponding to the area $p_1\, a\, b\, p_0$ in the diagram on p. 323, vol. vi), and that the energy transformed from heat is represented by the area $v_0\, v_2\, v_3\, v_1$ on the accompanying diagram (corresponding to the area $a\, c\, d\, b$). This area represents, consequently,

* Transactions of the American Institute of Mining Engineers, vol. vi, p. 313.

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the actual energy of the issuing air. A difference between this diagram and the similar one illustrating the effect of heating the blast is in the much smaller curvature in the former of the lines $v_0 v_1$ and $v_2 v_3$ (corresponding respectively to the lines $a b$ and $c d$ of the other diagram), representing the adiabatic expansion of the air. The curvature of each of these lines is indeed so small that its divergence from a straight line would be inappreciable, and it has been drawn as a straight line on the diagram. This is due to the fact that in the case of the chimney the difference in pressure is an extremely small fraction of the normal pressure. In consequence of this it has also been necessary to construct the ordinates, representing pressures, on a much larger scale than in the diagram for the hot blast.

It is clear from the foregoing discussion that in equation (4) E represents the energy of the issuing hot air. As the expression for $E\left(\frac{u^2}{2g}\right)$ is the same as that for the height of a column of air of the density δ_3, which would cause the velocity of efflux u, the equation giving the value of E expresses also the head, measured in hot air, which the chimney can create. I call attention to this fact because some confusion has existed with regard to it. It has been supposed that the expression which we have obtained for E, viz., $H\frac{T_2 - T_0}{T_0}$, represents the head produced by a chimney measured, not in hot air, but in cold air of the temperature T_0, and that u represents in consequence the velocity with which the cold air flows into the furnace. In the files of *Engineering* for 1878 and 1879 will be found a discussion by partisans of these two theories. Even Péclet fell into error upon this subject. In the third edition of his *Traité de la Chaleur* he states that the formula $H\frac{T_2 - T_0}{T_0}$ represents the head in cold air which a chimney can produce, basing his conclusion on some experiments which he had made to determine the comparative velocity of efflux of cold and of hot air. These experiments, however, as he admitted, were lacking in exactness, as the temperature was merely estimated, not measured. In the fourth edition of Péclet's work, the editor, M. A. Hudelo, proves, by a discussion based upon the principles of thermodynamics, that the expression referred to must represent the head in hot air.

By comparing the amount of heat converted into work by the chimney with the total expenditure of heat, we can get an idea of the efficiency of the chimney as a heat-engine.

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To each kilogram of air there is imparted by the chimney a quantity of actual energy equal to $H\frac{T_2 - T_0}{T_0}$ kilogrammeters. The quantity of heat thus converted into work is equal to $AH\frac{T_2 - T_0}{T_0}$ in which expression A represents the heat equivalent in calories of one kilogrammeter.

The total expenditure of heat is represented by the expression $S_p(T_2 - T_0)$. The ratio between these two quantities is the coefficient of useful effect of the chimney as a heat-engine.

$$C = \frac{AH\frac{T_2 - T_0}{T_0}}{S_p(T_2 - T_0)}.$$

But

$$A = \frac{\gamma - 1}{\gamma} S_p \frac{T_0}{p_0 v_0}$$

Consequently

$$C = \frac{\gamma - 1}{\gamma}\frac{H}{p_0 v_0} = 0.29\frac{H}{7991} = 0.0000363\ H.$$

The denominator, $p_0 v_0 = 7991$, represents the height in meters of a column of air at the uniform density δ_0, which would produce the normal atmospheric pressure p_0. As H represents the height of the chimney, which rarely exceeds 100 meters, it is evident that even for the highest chimneys the coefficient of useful effect is extremely low.

If, for instance, $H = 50$ meters, $C = 0.001814$. In this case the heat utilized is less than two-thousandths of the heat expended.

It is worthy of remark that the coefficient of useful effect of a chimney, as a heat-engine, depends only upon the height of the chimney, to which it is directly proportional, and that it is entirely independent of the temperature within the chimney.

To explain this low degree of efficiency let us substitute in the expression for C the value of H given by equation (5).

$$C = \left\{1 - \left(\frac{p_2}{p_0}\right)^{\frac{\gamma - 1}{\gamma}}\right\} = \frac{T_2 - T_3}{T_2} = \frac{T_0 - T_1}{T_0}.$$

The low degree of efficiency of the chimney is due to the very slight fall of temperature which the air suffers in expanding, and this is occasioned by the small difference between the atmospheric pressure

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at the top, and that at the base of the chimney. A chimney might be compared, in this respect, to a non-condensing steam engine, in which the pressure of admission of the steam was but a few grams per square centimeter, or an ounce or two to the square inch.

To see how small these differences of temperature and pressure are, let us determine them for a special case. Let $H = 50$ meters, $T_2 = 546°$, consequently $t_2 = 273°$ C.

$$\frac{T_3}{T_2} = \frac{T_1}{T_0} = \left(\frac{p_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}} = 1 - \frac{\gamma-1}{\gamma}\frac{H}{p_0 v_0}$$

$$\frac{T_3}{T_2} = \frac{T_1}{T_0} = \left(\frac{p_2}{p_0}\right)^{0.29} = 1 - 0.29\,\frac{50}{7991} = 0.9982.$$

$p_2 = 0.99376\ p_0 = 10268.48$ kilograms per square meter.
$p_0 - p_2 = 0.00624\ p_0 = 64.48$ kilograms per square meter.
$T_3 = 0.9982\ T_2 = 545°$, $t_3 = 272°$.
$T_1 = 0.9982\ T_0 = 272.5°$, $t_1 = -0.5°$.
$t_2 - t_3 = 1°$.
$t_1 - t_0 = 0.5°$.

The fall in the temperature of the air, in consequence of its expansion as it rises in a chimney 50 meters high, is only 1° C., when its initial temperature is 273° C.; but even the small quantity of heat corresponding to this decrease of temperature is twice as great as that ultimately converted into work, for the compression of the external air from p_2 to p_0, according to our assumption, causes its temperature to rise half a degree from T_1 to T_0.

A common method of measuring the efficiency of a heat-engine is the determination of the consumption of fuel which it requires per hour and per horse-power.

We can estimate this quantity for a chimney: Let n = the number of kilograms of air delivered by the chimney per second, and let $H.P.$ = the horse-power of the chimney. An engine of 1 horse-power is capable of performing a work of 75 kilogrammeters per second:

$$H.P. = \frac{n}{75} H \frac{T_2 - T_0}{T_0}.$$

Let b = the number of kilograms of coal burned per hour, and c = the number of calories utilized in heating the air per kilogram of fuel burned.

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It is evident that bc = the amount of heat absorbed per hour by the air. But this quantity of heat must equal the product of the weight of air heated by its specific heat and by the rise in its temperature. We have thus:

$$bc = 3600\, n \times 0.2375 \times \left(T_1 - T_0\right).$$

From this, and the expression for *H.P.* given above, we obtain:

$$\frac{b}{H.P.} = \frac{75 \times 3600 \times 0.2375 \times T_0}{cH} = \frac{17507125}{cH} \qquad (6.)$$

If c = 8000 calories, rather a high estimate,

$$\frac{b}{H.P.} = \frac{2188}{H}.$$

If H = 50 meters

$$\frac{b}{H.P.} = 43.8.$$

The consumption of fuel required by a chimney of this height to supply the power for producing the draught is 43.8 kilograms per horse-power per hour; more than forty times the consumption of the best modern steam engines. It is true that in the case of the chimney the power is applied directly to the air, and that, in consequence, the loss in its transmission through mechanism is avoided; but this advantage is very far from compensating the chimney's low degree of efficiency as a heat engine. Assume, for instance, that a fan with a coefficient of useful effect of but 0.25 is driven by a steam engine of comparatively low efficiency, consuming 4 kilograms of coal per indicated horse-power per hour; the consumption of fuel in this case would be 16 kilograms per effective horse-power per hour, less than two-fifths of that required by the chimney.

Even for mines, where H, representing the depth of the upcast shaft, can much exceed the height of the highest chimney, furnace-ventilation can be proved to be theoretically, as it has been found practically, inferior in efficiency to mechanical ventilation, except for very great depths. Guibal fans have been found to give a coefficient of useful effect, varying from 0.30 to nearly 0.75. Assume a coefficient of only 0.40, and a steam engine as motor requiring as much as 4 kilograms of coal per indicated horse-power per hour; mechanical ventilation would, under these circumstances, require a consumption of 10 kilograms of coal per effective horse-power per hour.

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In the case of furnace-ventilation the amount of heat utilized in heating the air to the mean temperature of the upcast shaft is not likely to exceed 5000 calories per kilogram of coal burned.

The depth of shaft, at which furnace-ventilation would equal in efficiency the imperfect type of mechanical ventilation described above, can be obtained by substituting for c in equation (6) 5000, and for $\frac{b}{H.P.}$ 10, and solving the equation with reference to H. thus:

$$H = \frac{17507125}{10 \times 5000} = 350.$$

It would require a shaft 350 meters deep to render furnace ventilation as efficient as mechanical ventilation of this comparatively imperfect type.

Suppose, now, that the fan has a coefficient of 0.60, and that it is driven by a compound condensing engine of the best modern construction, requiring, say, 1.2 kilograms of coal per indicated horse-power per hour; in this case 1 effective horse-power would be developed by the combustion of 2 kilograms of coal per hour. Let us also suppose that the furnace-ventilation could be so improved that 6000 calories could be utilized for each kilogram of coal burned; under these conditions the depth of shaft, at which the efficiency of the furnace would equal that of the fan, would be given by the equation:

$$H = \frac{17507125}{2 \times 6000} = 1459.$$

This latter value for H (1459 meters) considerably exceeds any depth as yet attained in mines.

The reason for this inferiority of furnace-ventilation is evidently the same as the cause of the chimney's small efficiency. The difference between the pressure of the air at the bottom of the deepest shaft and that at the surface is so small a fraction of the former, that the fall in temperature of the air, owing to its expansion as it rises in the upcast shaft, is a very small fraction of the absolute temperature which it possesses when it enters the shaft. Consequently, a very small portion of the heat communicated to the air is utilized by conversion into work. This fact does not seem to have been clearly apprehended by all writers on the subject. André, for instance, in comparing the two methods of ventilation, remarks: "With a properly constructed furnace and a fairly dry shaft it is hard to see, when

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we consider how the heat is applied in the two cases, how the advantage can be on the side of the machine."*

To return to the chimney; it is evident from our discussion that it is a most wasteful form of heat-engine, and that a certain supply of air can be furnished by a fan, or other blowing machine, with a smaller expenditure of heat than by a chimney. It may seem surprising, in view of these facts, that chimneys have not long since been superseded by more perfect apparatus for producing currents of air. It must be borne in mind, however, that to realize the full economy incident on the substitution of a fan for a chimney it is necessary that all the heat be utilized which would otherwise escape through the chimney. The temperature of the products of combustion of the fuel must be reduced to that of the external atmosphere before they are allowed to escape, and the heat thus abstracted from them must be applied to some useful purpose. This is frequently impracticable. Owing to the disagreeable and deleterious nature of the gases issuing from furnaces it is frequently necessary that they be discharged at a considerable height above the surface, in order that they may be diluted with much pure air before coming into contact with animal or vegetable organisms. A chimney of some kind is, therefore, in general a necessity; and, since it is frequently impracticable to utilize completely the heat of the gases of combustion before they reach the chimney, it is plain that in such cases it is well to apply to the generation of a draught the heat which would otherwise be wasted. Add to this the fact that a well-designed and well-constructed chimney requires, after being once put into operation, very little care or expense, continuing steadily and automatically to produce a draught, as long as the fire is properly tended, and it will be seen that its retention is in many cases justifiable on the score of economy. Indeed, in many instances where fan-blast has been substituted for chimney-draught, the governing motive has been, I conceive, not economy in the performance of the work of supplying the air, but rather the attainment of other advantages incident on the use of blast; chief among these are a greater facility of controlling the combustion in the fireplace, and the avoidance of an in-draught of air through the furnace doors. This latter advantage may prevent waste of a much more valuable material than coal, namely iron, as in the puddling or heating furnace.

Notwithstanding all this, however, it may be safely stated as a

* A Practical Treatise on Coal Mining, page 497.

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sound, general rule of practice, that fireplaces and furnaces on a large scale should be so designed that no heat which can be otherwise utilized shall be applied to the production of draught through the chimney.. The application of this rule would result in substituting fans or other blowing machines for chimneys in some cases, in others it would cause the chimneys to be designed with large dimensions, so that they could produce the requisite draughts with a comparatively low temperature of the escaping gases.

By changing the usual arrangement, and placing the chimney between the fireplace and the furnace, it would be theoretically possible to produce draught by a chimney without any waste of heat. The efficiency of the chimney as a heat-engine would not thereby be improved, but, as the heat rejected by it would be utilized in the furnace, the result would be a complete utilization of the heat, provided the temperature of the gases could be reduced to that of the external atmosphere before they left the furnace. There would be the further advantage that a chimney of given dimensions would produce a more active draught than by the usual arrangement, since the gases within it would be very hot, having very nearly the temperature of the fireplace. To produce a certain draught, therefore, a smaller chimney would suffice. The structural difficulties, however, connected with this arrangement, since it would require the furnace to be built on a level with the top of the chimney, would in most cases render it inapplicable. Besides this, it would be difficult in practice to avoid a considerable waste of heat by transmission through the walls of the chimney, filled, as it would be, with highly-heated gases. It is possible, however, that under some exceptional conditions it might be advisable to adopt this arrangement.

INSTRUMENTS FOR PROJECTION DRAWING.

BY PROFESSOR J. M. SILLIMAN, LAFAYETTE COLLEGE, EASTON, PA.

ISOMETRICAL drawing and clinographic projection are generally preferred to perspective drawings for representation of small objects or complicated mechanisms, as they present to the eye a sufficiently accurate picture of the object, while they possess great advantages over perspective in the simplicity and rapidity of execution, and the facility they give for taking measurements directly from the drawings.

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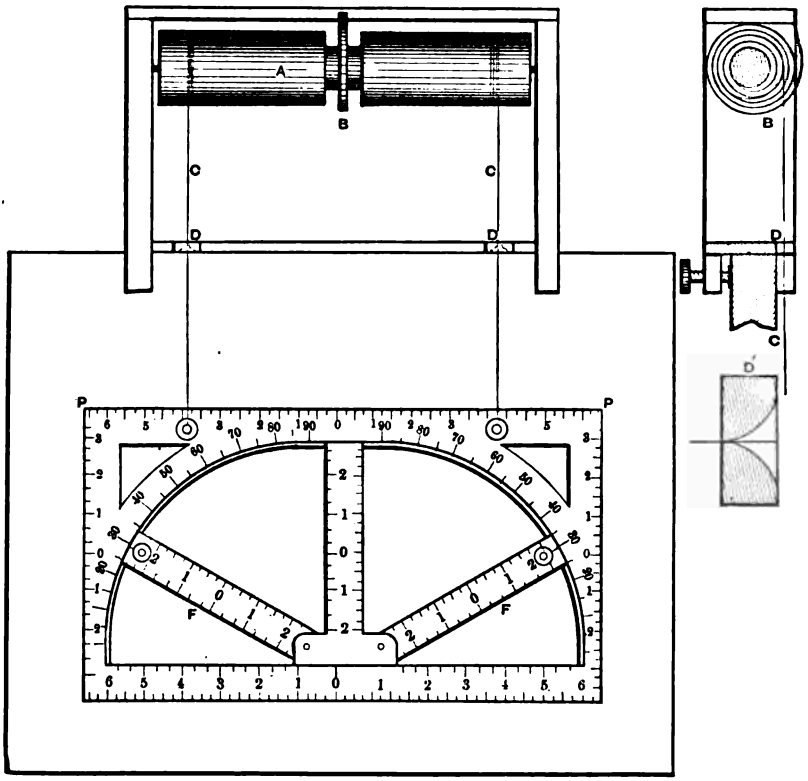
The object of the instrument here described is to facilitate constructions to any desired scale in isometrical drawing, cabinet and crystallographic projection, and stress diagrams in graphical statics. As shown in the accompanying drawing (Fig. 1), it consists of a frame, which may be readily clamped to any drawing-board, having at its further extremity an accurately turned revolving cylinder *A*, actuated by an adjustable spring *B*, which tends to wind upon it the two fine wires shown at *c c*, which, passing through the eyes *D*, are attached to the drawing-frame by clamping screws. This frame is adjusted so as to bring its edge *PP* parallel to the line *DD*

Fig. 1



through the eyes. The frame may be freely moved to any part of the drawing-board, the wires while winding or unwinding being kept taut by the action of the spring.

The eyes, through which the wires pass, are turned by a tool whose cutting edges are quadrants, so that a uniform distance may be maintained between the points of contact at the eyes when the frame

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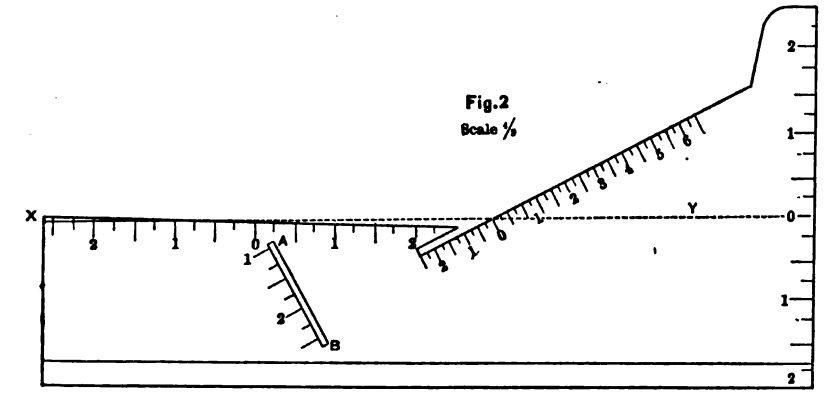
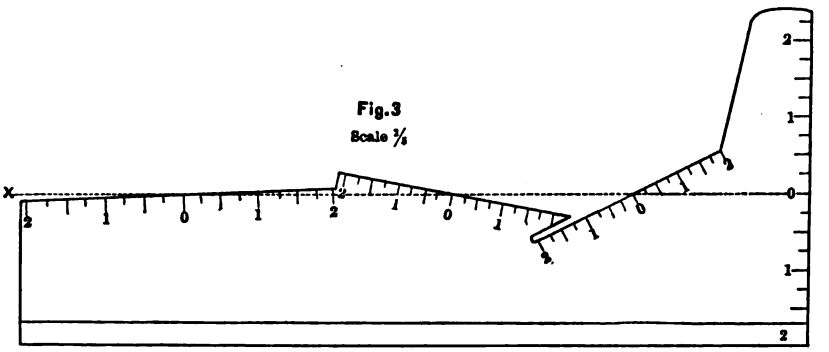
is swung to the right or left, and there will be no kinking of the wires. A section of one of the eyes on a larger scale is shown at D′. By this arrangement all the edges of the drawing-frame preserve their parallelism in all positions on the board. The drawing-frame is rectangular, having graduated edges bevelled to $\frac{1}{80}''$ thickness that they may be used both as scales and rulers. The movable arms *FF* can be clamped at any angle, and are shown in position for isometrical drawing.

For cabinet projection an arm may be clamped in any assumed direction for the projection of the co-ordinate line which is perpen-





dicular to the plane of the paper. In the execution of these drawings, any line parallel to a co-ordinate axis may be constructed by moving to the required point the zero point of the edge set to that axis, when the line of any desired length may be immediately drawn. One set of edges is divided into $\frac{1}{16}''$, and the other set parallel to the first into $\frac{1}{80}''$, thus enabling the construction of drawings on a great variety of scales.

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By adding to the frame two arms pivoted at *PP*, moving outwards from the vertical, and by setting one in the direction of a ray of light as projected, and the remaining three in the directions of the projections of the ray on the co-ordinate planes, the outlines of shadows may be rapidly drawn. The side arms may also be advantageously used in construction of stress diagrams in graphical statics. The drawing-frame can be temporarily removed from the board by simply inverting it over the roller.

The drawing of crystals is greatly facilitated by the use of a frame actuated on the same principle, provided with edges having the required directions and graduations to represent the axes of crystals in the rectangular and hexagonal systems. Forms for this purpose intended for use with the *T* square are shown in Figs. 2 and 3. The first is for the drawing of crystals in all the systems except the hexagonal, and the second for the hexagonal. In these the edges have the directions of the projections of the axes and the required graduations; the zero points of the scale being on the same horizontal line *XY*, so that by sliding the scale along the *T* square, the axes may be successively drawn to any scale, and any measurements required during the drawing of a crystal may be readily made.

In drawing crystals in the isometric system it is frequently convenient to make use of an auxiliary circumscribing cube, the lower front right corner of which may be pricked off on the scale *AB* while the point *O* of the scale on the left is at the centre.

TOPOGRAPHICAL AND GEOLOGICAL MODELLING.

BY O. B. HARDEN, PHILADELPHIA.

In working out the geological structure of a complicated district, where the problems are difficult to solve by the ordinary methods in use, a model, upon which all the geological and topographical data may be put, will be found of great value, bringing, as it does, all the facts in their proper relationship at once under the eye. In the teaching of structural geology, also, a model is of great value, since the student can thus have before him, in miniature, a representation of the rocks, as he would see them in place. Topographical models may often be useful in suits at law for damages in railroad accidents, or for trespass against mining companies, etc., in order

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to show the jury an accurate representation of the surface or underground features in dispute before them, without going out of court; and, in any case where a more graphic representation is needed than is given by an ordinary map, as, for example, when a board of directors wishes to know the precise positions of mines, furnaces, or other pieces of property, a model answers all requirements. A good model has, furthermore, an æsthetic value, for, when colored to nature and tastefully framed, it is not only a work of science, but of art.

The method here described is that adopted by Professor Lesley in modelling for the Second Geological Survey of Pennsylvania, and is very ready and accurate. The prerequisite to a good model is, of course, a good map, with the elevations represented by contour lines. Intervals between contours corresponding to a difference of 10, 20, or 100 feet in altitude will be found most useful, according to the scale adopted. In a strictly accurate model the vertical and horizontal scales would be the same, for, if the vertical be larger, the height of the mountains and dip of the rocks will be exaggerated; but where a large area of country is modelled, the height of the mountains and ridges bears such a small ratio to the area to be represented that such a model seems very flat, and conveys but a faint idea of the topography as it would appear, to any one but an experienced topographer, in walking over the ground. The vertical scale is, therefore, advantageously made greater than the horizontal, to give the general impression which the topographical features would have in any particular locality. The models of the Survey, with one or two exceptions, have been made, however, with both scales alike.

A base large enough to represent the area to be modelled is made by screwing planed boards together of a sufficient thickness for strength. The lowest contour line is then traced upon the base with a stylus and black paper, care being taken to register correctly as often as the map is laid upon it. The lumber used by cigar-box makers is best suited for modelling, if of a thickness required by the vertical scale, and it can be obtained planed to order without extra expense. The thinnest boards obtainable will average about $\frac{1}{16}$ of an inch in thickness. On a scale of 1600 feet to an inch a board $\frac{1}{16}$ of an inch thick, will, of course, represent 100 feet in height. The lowest contour line and the one next above it are then traced upon a board, or boards, cut the exact size of the base, and temporarily nailed upon it. The board is then cut along the lower, or outer one, of the two contours (following the windings of the line with

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great care) with a little jig-saw, such as is used for making scroll work, brackets, etc. The upper, or inner, line is left to register the next layer of boards. After the board is marked, a few dowel holes should be put through it with an awl, into the boards below, to insure the pieces going into their proper places after being cut. The board is nailed to the base with little sprigs, enough sprigs being used to prevent the boards from springing. A magnetic hammer can be used to advantage in lifting the sprigs, and putting them in place. Care must be taken not to split off the ends of the boards where they form the end of a mountain or ridge. Should this occur, they can be stuck on with glue, which should also be used where sprigs would split the board. The next higher contour line is then taken, and so on, until the highest elevations on the map are reached. The wax for shaping the model is made of the following ingredients: 16 parts of yellow beeswax, 8 parts of corn-starch, 1 part of Venetian red, 4 parts of Venice turpentine, and 1 part of sweet oil. This becomes quite plastic by the warmth of the hand, and is put on all over the model, filling in from the edge of one board to that of another, until it presents a smooth even appearance, and a *fac simile* of the topography. Considerable care and time are required in rubbing on the wax. No more should be put on than is required by the contours. The edges of the boards should just be seen through the wax. The tools used in the waxing are bone scrapers, like those used by moulders. Elevations of less than the thickness of a board can be put on with the wax, or the full thickness of the board may be put on, and reduced by sandpaper, as required by the elevation. The model is then varnished with shellac and rubbed well with linseed oil, care being taken to get the oil into all the low places, as on this depends the facility with which the negative can be removed after the setting of the plaster. Care must also be taken not to use too much oil, as an excess is likely to cause air-bubbles, that would produce corresponding depressions in the plaster negative. Four strips are now screwed around the model, so as to be plaster-tight and high enough to make the negative of sufficient thickness for strength. The model is then made level on the floor and the plaster is poured over it. The plaster, which should be of the best quality, is prepared by mixing with water, by the hand, until it becomes of the requisite stiffness, nearly approaching a paste, though liquid enough to pour, and is free from all lumps. In pouring the plaster, care must be taken to avoid the formation of air-bubbles. Should there be an insufficiency of plaster, more should be mixed and poured on

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without loss of time, for it soon sets; but even when great care is exercised, the two portions are liable to separate at their common surface. At least, this will be a weak place in the model. When the plaster has set to the condition of a clay, a straight-edge should be run over the top of the sides, to take off the superfluous material and to make the bottom of the negative level. It is then left to dry for half an hour, after which the side-pieces may be taken off, and the negative removed from the model. Before becoming dry, the plaster may be made perfectly smooth by rubbing with a linen rag. The negative, after being allowed to dry thoroughly, is scraped with tools made for the purpose. On the smoothing up of the negative depends the appearance of the positive after casting. In the negative, of course, the mountains appear as depressions, and the valleys as elevations, and if too much plaster is taken off of the bottom of the negative, it makes the mountains so much the higher. The negative is then coated with shellac varnish, oiled with linseed oil, and inclosed with four side-pieces, high enough to give the requisite thickness to the model. A cast is then made, which, when dry, is ready for the scraping process. The sides are also smoothed for the cross-sections. It is then varnished, and is ready for the paint. The plaster is very fragile, and, when large models are made, they have to be quite thick. Great care has to be taken in moving them to avoid any straining of the parts. The corners, too, require protection. The topographical features may be put on first in pencil as a guide in coloring. Oil colors are used, rubbed up with drying oil and turpentine. Railroads, towns, etc., may be represented in black; the streams in white. The outcrops of the different geological formations are put on in appropriate colors. If only one copy is needed, the wooden model may be painted, and serve as well as a plaster cast, only that the wood will shrink in time, and, perhaps, crack.

A very pretty specimen of this method of modelling is a "Geological Model of part of Blair, Bedford, and Huntingdon Counties, Pennsylvania," by Mr. E. B. Harden, from surveys by Mr. R. H. Sanders. It has been phototyped by Gutekunst, of Philadelphia, and published in the *Proceedings of the American Philosophical Society*, number 109.

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NOTES ON THE BEHAVIOR OF MANGANESE TO CARBON.

BY WILLARD P. WARD, A.M., M.E., SAVANNAH, GEORGIA.

I DESIRE to put on record a fact in relation to the effect of manganese on pig iron which I have never seen in print, and which may, perhaps, not have been observed by anyone except myself.

In 1875, while experimenting on the production of ferromanganese in a blast furnace, I had burdened the furnace with a charge which I calculated would produce a 15-per cent. spiegel. The furnace was *very hot*, having been running for a couple of days on a very light burden, and making a burnt iron, preparatory to the experiment I proposed to make to produce a high grade of spiegel. I calculated that the charge would begin to work in the furnace in about twelve hours after it was put on. After the lapse of that time I commenced to watch the furnace carefully, but found little or no change in the appearance of the metal, although there was a very decided change in the cinder, showing that the manganese ore had come in work. The iron was quite gray and very tough. The character of the cinder was good for a spiegel cinder, and I could not imagine where the manganese was going to, as it did not appear to be in either metal or cinder in anything like the quantity indicated by the charge. The next morning things were still in the same condition. The furnace was very hot, the cinder good, and the iron very gray. I was then sorely puzzled. I had never heard of a gray iron with over 4 or 5 per cent. of manganese, and had no notion that an iron with more manganese could be gray and tough. With great difficulty a piece for chemical test was broken from a pig. Not less than a hundred blows from a heavy sledge were required to break it off. I took the specimen to the shop and directed that some borings from it should be brought to the laboratory, as soon as possible, whither I myself at once repaired to put things in readiness for a rapid manganese determination. In about half an hour the machinist came in with the iron specimen in one hand and about a dozen blunted and broken steel drills in the other, saying that it was impossible to drill the iron. There were several little depressions in the iron, which was malleable enough to be indented by the point of the drill, but not a chip had been cut from it. The metal was never subjected to further physical tests. A chip broken from

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a sharp corner and analyzed showed 16 per cent. of metallic manganese.

Not long after it occurred I mentioned this phenomenon to the late Mr. A. L. Holley, who said that he had never heard of such characteristics being shown by so high an alloy of iron and manganese. Other gentlemen in the steel trade, to whom I have mentioned it, were equally surprised.

I have already mentioned that the furnace was abnormally hot at the time, and this, I think, accounts for the whole thing. I believe that at a sufficiently high temperature graphitic carbon will separate from manganese pig just as it will from an iron pig at a much lower temperature. If the temperature at which the metal is produced be too low, carbon will not separate from pig-iron. Furnace heat is hardly ever high enough to cause the separation of graphite in spiegeleisen, and hence it has seldom been observed. When the metal is produced at a high enough temperature to allow the deposition of graphite in spiegeleisen, the metal is tough and strong, just as gray iron is tough and strong, otherwise the metal containing combined carbon is hard and brittle, just as white iron is hard and brittle.

In discussing the effect of manganese on steel rails this observation may be of some value. It will be remembered that Dr. Raymond, at the Virginia meeting last spring, in the discussion of Dr. Dudley's paper, showed, by the application of the method of least squares to a hypothetical equation, that manganese had no effect on the wear of the rail. Now, if we admit my observation of facts to be correct, we have a practical confirmation of this mathematical demonstration. The temperature of molten wrought-iron, which prevails in the Bessemer converter when the spiegeleisen is added, is certainly higher than that of the furnace when I made gray manganese pig, and the manganese may very likely exist in the rail in the same condition that it did in my pig; if so, it should have a tendency only to make the rail hard and tough, thus increasing its wearing power, but only to a very slight degree, as the amount of manganese is very small in proportion to the iron. Hardness in a rail cannot be objectionable unless it is accompanied by brittleness.

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COALS IN MEXICO—SANTA ROSA DISTRICT.

BY W. H. ADAMS, M.E., CHICAGO, ILL.

I DOUBT if many of our engineers know of the existence of coal-fields extending over hundreds of miles of territory bordering on and lying contiguous to the Rio Grande River in Mexico. Essential as these facts are to those contemplating the starting of industrial works along our frontier, I have not been able to learn that any surveys or examinations have been made of these deposits, and I trust the preliminary and unofficial investigations lately made by myself may be found of interest, especially to those of our members whose experience has been with poor fuel, or in districts remote from railway facilities. While it is true that Northern Mexico is generally bare of charcoal-making timber, yet no greater mistake can be made than to condemn the light, quick-growing woods found in profusion, and which cannot be excelled in flame or heat-producing qualities for boilers, reverberatory furnaces, or hearths. No country could be surer of a full supply of wood if wise legislation in regard to irrigation and preservation of young timber were adopted and enforced, but the beneficiation of the low-grade ores of Mexico demands a more dense fuel for furnace work, and, fortunately for metallurgists, who will hereafter make this frontier a base of operations, there have been disclosed, near the surface, seemingly inexhaustible beds of semi-anthracite and bituminous coals.

No extensive openings have as yet been made, and my own workings at the Cedral mines are all that can yet be said to prove the quantity and quality of the coal, other openings furnishing only corroborative evidence. Our location (one hundred and ten miles west of the Rio Grande River) is on the western line of the depository basin, as it has existed since the period of activity along the volcanic line. The region farther inland I have not examined, but the elevations, as a rule, are much greater, though from the nature of the formation, they are not necessarily barren ground.

Beginning at the base of the Santa Rosa Mountains (location of the Cedral mines), we find very interesting breaks in the foot-hills, disclosing the stratified rocks from the volcanic centres to the valleys.

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Nearly every inclination of dip, from horizontal to vertical, tells the story of plutonic forces exerted for an incalculable period of time; and at elevations, for from fifty to seventy-five miles around, we find basaltic lavas, covering the foot hills, while over the surface of the great plains, that extend two hundred and fifty miles to the eastward, waves of trachytic lavas are found imbedded in deposited limestone. The seat of volcanic action can be perfectly located at several points along the range, and in every case the eruptive forces have laid bare the stratification to such an extent that there is no difficulty in locating the line of transition rocks. Dikes of slate which mark their inner boundary are found invariably at certain distances from the largest known deposits of silver-bearing ore, and have been pointed out by myself as positive indicators of the presence of valuable vein matter, inasmuch as the strata of slate, which yield readily to pressure without losing their cohesiveness, form a dam or wall, behind, or in, which all metallic substances were held until changed chemically or deposited by gravity in seams of the easily broken limestone. No better instance can be found of deposition of silver in its various forms—sulphide, chloride, antimonide, etc.,—in transition slates than is here seen, where several large workings are open to inspection. From their nearness to the coal measures, the mountains, which are protruded into the plains at this particular point, offer a great novelty in producing vertical veins of coal nearly anthracitic in character, which I have opened to a depth of 240 feet. Coal of a more bituminous nature is found outcropping on the rivers thirty, forty, and sixty miles to the eastward, and lignites are met with in many places over a wide extent of country drained by the Rio Grande River. The inference is that the heat which changed the metamorphic rocks, drove off the bitumen, and that the nearer one approaches the mountain-line the better is the product.

The rocks may be classed as Triassic, all the characteristic features being here observable; such as indurated clays of varied colors; gray compact limestones, dolomitic in places; variegated and even bright-red sandstones, silicious and argillaceous; gypsum in beds; and rock-salt evidently in enormous quantities at no great depths, as the streams, pools, and lakes are more or less saline over the entire southern portion of the basin. Artesian wells along the line of the Mexican National Railway, about Lampasos, invariably show salt water before and after reaching the coal seams, and brackish water is also found in the northern belt-line, while the central portion affords unlimited supplies of pure water from stratified lime-

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stone. To the eastward, breaks in the horizontal strata disclose sandstone, shales, fuller's-earth, grit-stones, etc., while surface openings at several points along the Sabinas River, above ordinary water level, show veins of coal of good workable thickness and excellent quality. The amount of sulphur contained in the coal is considerable, and finely disseminated, but not so great as to require a washing operation.

Passing farther to the east, openings have been made about Eagle Pass, in a circuit of twenty miles in Mexico, and notably at the mouth of Seco Creek. Surface indications are, however, observable over the plains at numberless points between mountain-chain and river. At Eagle Pass the Permian system undoubtedly commences, the gray and green-white sandstone showing itself in the bed of the river, and at several places along the Rio Grande River the opportunities for observation are equally perfect. Here the character of the coal changes, and lower grades of bituminous coal and shales are found in wide veins, but so mixed with clay and grit as to be of little value commercially, so far as yet developed. I cannot believe these beds to be brown coal or lignites, as generally stated, the geological formation being certainly too old for lignite; and although we have examples of good coal in the Tertiary, I know of no evidence of the presence of lignites in the Permian.

Down the river more recent formations outcrop, and in the neighborhood of San Antonio true brown coals of woody texture are found. Without a knowledge of the lines of upheaval, which are generally easily traceable, the casual observer would not note that Eagle Pass is, say, 500 feet higher than San Antonio, with all the strata inclining towards the latter, and showing the coals of Eagle Pass to belong to an older period.

The future commercial value of this basin of coal (which underlies one of the richest agricultural districts of Northern Mexico, and adjoins a mineral chain of known large extent and exceptional richness) is yet to be determined. At present my own work is upon the upheaval veins, and, being preparatory only, differs in no way from ordinary work on a perpendicular vein. The coal cokes easily, producing about 60 per cent. in weight of good coke, and while I am not now prepared to give details or analyses, yet the extended underground workings and the new bank of fifty ovens to be erected this spring will furnish a practical demonstration, which I shall be pleased to show to travellers.

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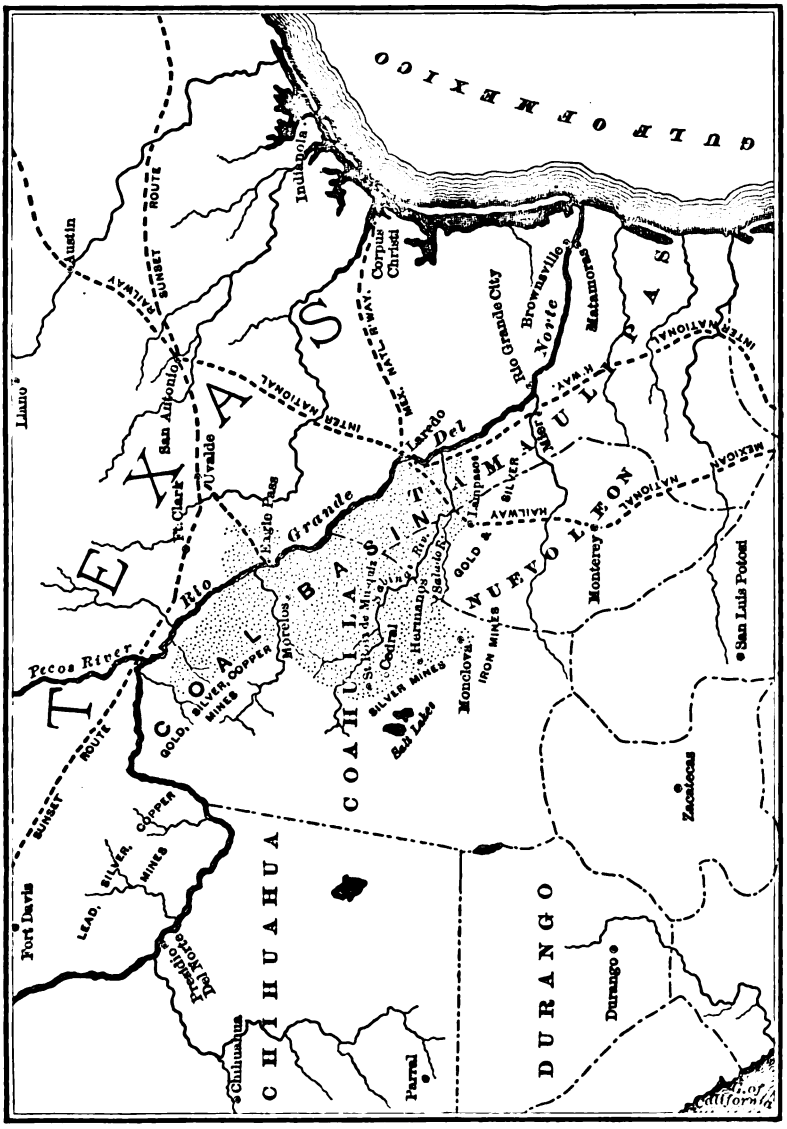
The accompanying map will assist the reader in locating this district.



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LATE DEVELOPMENTS IN THE SIEMENS DIRECT PROCESS.

BY GEORGE W. MAYNARD, NEW YORK.

In this paper I desire to embody the results of some personal observations of the working of the Siemens direct process as I witnessed it for a part of three days at the works of the Siemens-Anderson Company, in Pittsburgh. This preliminary investigation was to have been followed up by one extending over a considerable period of time, and would have embraced analytical and physical tests. Circumstances over which I had no control, resulting in the temporary suspension of work, have postponed the presentation of a complete paper. If the opportunity is afforded me, I purpose doing this at a future meeting of the Institute. To those interested in the development of the process, reference is made to the papers of Dr. Siemens in the *Journal* of the Iron and Steel Institute for the years 1873 and 1877, and to the paper of our late lamented brother, Holley, in the 8th volume of the *Transactions* of our own Institute.

Dr. Siemens, in the introduction to his paper "On the Manufacture of Iron and Steel by Direct Process," read before the Iron and Steel Institute in September, 1877, says: "In mixing comparatively rich iron ore in powder with about 25 per cent. of its weight of pounded coal, and in exposing this mixture for some hours to the heat of a common stove or of a smith's fire, metallic iron is formed, which, on being heated to the welding-point on the same smith's hearth, may be forged into a horseshoe of excellent quality. The admixture with the ore of some fluxing materials, such as lime or clay, will, in most cases, be of advantage to rid the iron of adherent slag." This is the keynote of the Siemens direct process.

Dr. Siemens says further: "If we regard the production of wrought iron from an abstract point of view, we perceive that we have to accomplish two things, viz., the deoxidation of the ore, and the fusion of the earthy matter mixed with it; and if we calculate the amount of carbon necessary to accomplish this end, we shall find that in using, say, hematite ore, consisting of peroxide of iron with from 10 to 15 per cent. of silica, we shall require barely 40 per cent. of carbonaceous matter per ton of iron contained in the ore to effect its reduction, and also the fusion of the slag."

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In Dr. Siemens's own language, the rotative furnace is worked as follows: "The ore to be smelted is broken up into fragments, not exceeding the size of peas or beans; to it is added lime or other fluxing material, in such a proportion that the gangue contained in the ore and flux combines, with only a little protoxide of iron, into basic and fluid slag. A charge of, say, 20 cwt. of ore is put into the furnace, when fully heated, while it is slowly revolving. In about forty minutes this charge of ore and fluxing material will have been heated to bright redness, and at the same time from 5 to 6 cwt. of small coal of uniform size are added to the charge, while the rotative velocity is increased, in order to accelerate the mixture of coal and ore. A rapid reaction is the result; the peroxide of iron, being reduced to magnetic oxide, commences to fuse, and at the same time metallic iron is precipitated by each piece of carbon, while the fluxing materials form a fluid slag with the siliceous gangue of the ore. The slow rotative action is again resorted to, whereby the mass is turned over and over, presenting continually new surfaces to the heating lining, and to the flame within the rotator. During the time of this reaction, carbonic oxide, besides the hydrocarbon contained in the coal, is evolved from the mixture of ore and carbon, and heated air only is introduced from the regenerator to effect its combustion within the rotating chamber. The gas from the gas producers is entirely, or nearly entirely, shut off during this portion of the process. When the reduction of the iron ore is thus nearly completed, the rotator is stopped in the proper position for tapping off the fluid cinder. After this the quick speed is imparted to it, whereby the loose masses of iron contained in it are rapidly collected into two or three metallic balls. These are taken out and shingled in the usual way of consolidating puddled balls; the furnace is tapped again and is ready to receive another charge of ore. In comparing upon theoretical grounds this method of producing metallic iron with the operation of the blast furnace, it will be at once perceived that, whereas in the blast furnace, the products of combustion consist chiefly of carbonic oxide and issue from the top of the furnace at a temperature exceeding 350° C., the result of combustion in the rotative furnace is carbonic acid, which issues from the regenerative furnace into the chimney at a temperature rarely exceeding 175° C. This proves at once a great probable saving of fuel in favor of the proposed method, and this saving is increased by the amount of coal consumed in the puddling process. It may, however,

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be asked why the rotating furnace should admit of the complete combustion of carbon, whereas in the blast furnace such complete combustion is, as is well known, not possible, because each atom of carbonic acid formed would immediately split up into two atoms of carbonic oxide, by taking up another equivalent of carbon from the coke present. The following explanation will serve to elucidate this point: In the rotative furnace streams of carbonic oxide are set up within the mass under reaction; and this carbonic oxide, on reaching the surface, meets the current of intensely heated air proceeding from the regenerators, and completes with it perfect combustion within the free space of the chamber. The carbonic acid thus generated comes in no further contact with carbon, consequently it cannot split up, but is drawn away unchanged into the chimney, while the evolved heat is taken up by the sides of the chamber, and transmitted by reverberation and conduction to the mixture of ore, fluxes, and coal."

In the same paper from which the above extracts have been made, Dr. Siemens said: "Although I have not yet been able to determine accurately the amount of fuel consumed in the gas producers, I feel confident that a ton of iron balls is produced in a full-sized rotator, working continuously, with a total consumption of fuel not exceeding 25 cwt., and a ton of cast steel will be produced with a consumption of 40 cwt. of common coal."

Later on we shall see if the results of late obtained begin to justify the prophecy. The process was introduced into the United States at the works of Park, Bro. & Co., Pittsburgh, in 1878. After a time it was pronounced a failure. The reason for this verdict was their inability to manufacture bar iron from the hammered bloom, the excessive oxidation naturally causing a great loss. ' It is somewhat remarkable that both Dr. Siemens and the Messrs. Park should have made the same mistake. The balls are made up of particles of pure iron and more or less fluid slag; the almost entire absence of carbon and the rapid oxidation deprives them of cohesiveness, so that any effort to make iron by simply shingling, reheating, and rolling must fail. All experience up to the present has taught us that the blooms are eminently fitted for the open-hearth process, and for this alone. Great credit is due Mr. R. I. Anderson, of Pittsburgh, for having erected a rotator at Tyrone, and for having boldly increased the dimensions of the furnace much beyond those of Dr. Siemens's furnace at Towcester. The Towcester furnace was

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9½ feet long by 8½ feet in diameter, and took a charge of 30 cwt. of ore mixed with 8 cwt. of small coal. The Tyrone rotator was 11 feet by 11 feet. On referring to Mr. Holley's paper, I find that in an average week's work with highly siliceous ore having about 50 per cent. of iron, the charges were: Ore, 4000 pounds; reducing coal, 600 to 700 pounds; limestone, 250 pounds; scale and cinder, 800 pounds. The yield of blooms was 1600 to 1700 pounds per charge, or 80 to 85 per cent. of the iron in the ore. The producer coal was 3800 pounds per ton of blooms. The week's work was 19 operations producing 14 tons of blooms. The results obtained at Tyrone were considered sufficiently satisfactory to warrant the construction of a large plant at Pittsburgh by the Siemens-Anderson Steel Company. This plant is located two and a half miles from Pittsburgh, on the Monongahela River, at what is known as the "Upper Works." It is built on a side hill, and is well arranged for economical handling of materials. A side track from the Baltimore and Ohio Railroad comes in on the upper level, where coal, ore, and limestone are delivered on to the platform leading into the crusher house. There are two of Blake's largest sized crushers, which discharge into small ones placed below, where the ore is reduced to the necessary fineness for treatment in the rotators. By means of continuous bucket belts, the ore is elevated to bins placed over a tramway, which extends into the reducing house and over the rotators. From the time that the ore, coal, and limestone are charged into the Blake crushers, there is no handling of material until the cinder and finished product is ready to be drawn. The hopper car holds a full charge. The ore as delivered is very wet, and it should be dried by some simple device, such as a revolving cylinder used for drying ores at stamp mills. The rotator plant consists of four vessels measuring 11 feet 4 inches in diameter and 12 feet in length inside the shell. The vessels are lined with Woodland fire-brick 4½ inches thick. The bricks stand well, but the shrinkage is said to be about one-sixth of the original volume of the brick. The brick lining is glazed by melting roll scale in the rotator and revolving it, and fettled by the addition of ore. From 24 to 48 hours are required for the thorough lining of a furnace. The entire charge of ore, limestone, and reducing coal is introduced at once. The vessel is slowly rotated at the rate of one revolution in every 15 to 18 minutes. In about four hours the slag begins to form, and when it becomes perfectly liquid is tapped off. The flow of slag continues until the completion of the

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heat and drawing of the balls. I witnessed the whole or part of 14 heats during my stay, viz., the drawing of some of those charged on the day before my arrival, together with the entire work from the charging to the drawing of the heats during my stay. The ores employed were a red hematite from Lake Superior, from the Dalliba Mine, said to average 60 per cent. in metallic iron, and a brown hematite from Tyrone, said to average 40 per cent. There has not been sufficient time to have analyses made under my own observation.

In view of the fact that the men, previous to the starting of the rotators, had had no experience in this kind of work, they certainly acquitted themselves very creditably. More skill, however, is required in shingling, but this will soon be attained. In looking over the record of 80 heats, which represent the number where iron has actually been produced, one cannot but be impressed with the favorable results. There has been less of failure than usually attends the starting of a new plant and new process with unskilled labor. I have the details from which the following summary has been made up:

Week ending	Ore used, pounds.	Iron obtained, pounds.	Per cent. result.
December 3d, . . .	46,750	15,761	34.3
December 10th, . .	137,000	36,713	29.3
December 17th, . .	164,600	76,080	46.2
	Result of 31 heats.		
December 19th–22d,	102,700	48,482	47.
	Result of 21 heats.		

For the week ending December 10th, the low-grade brown-hematite ores were used for the most part. Where ores of more uniform grade were used the percentage result has been improving. Several charges with Lake Superior and Tyrone ore have yielded over 50 per cent., and I have no doubt that an average of 50 per cent. can be kept up with this mixture. The average time for 48 heats, through good and bad, from the charging of the ore to the drawing and shingling of the balls, has been a little over nine hours. With more experience the time will be reduced to eight hours, or 3 charges in twenty-four hours, and a product of 15 tons of blooms. The present force of 35 men would be adequate for 6 rotators, so that it will be seen that the labor cost on the ton of blooms may be materially reduced. The pay-roll at present is as follows:

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	Per day.
Two crushers,	$1 25
One laborer,	1 25
Two laborers filling cars,	1 25
Two engineers,	2 00
Two firemen,	1 50
Two shinglers,	3 00
Two shinglers' helpers,	2 00
Two heaters,	3 00
Two heaters' helpers,	2 50
Eight furnacemen,	1 40
One cinder wheeler,	1 25
Two gas-makers,	2 00
Four gas-makers' helpers,	1 35
Two laborers unloading cars,	1 25

For the week ending December 12th, 38 tons of hammered blooms were produced, of which the details of cost were:

59 tons Lake Superior ore, at $8,	$472
15 tons Tyrone ore, at $4,	60
600 bushels reducing slack, at 4 cents,	24
4 tons limestone, at $1,	4
2650 bushels producer coal, at 6 cents,	159
Pay-roll,	351
38 tons.)	$1070
Per ton,	$28 16
Repairs and sundries,	2 00
Cost per ton,	$30 16

But in regular working the rotators would have produced 90 tons; therefore, under this assumption, we have:

144 tons Lake Superior ore, at $8,	$1152 00
36 tons Tyrone ore, at $4,	144 00
1440 bushels reducing slack, at 4 cents,	57 60
9¼ tons limestone, at $1,	9 25
6300 bushels producer coal, at 6 cents,	378 00
Pay roll,	351 00
90 tons.)	$2091 85
Per ton,	$23 24
Repairs and sundries,	2 00
Cost per ton,	$25 24

Dr. Wuth informs me that his analyses of the blooms have shown them to be of exceptionally good quality, while the steel

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made with them in the open hearth is superior to that made with scrap iron or scrap steel, usually purchased for decarburizing. I am informed that the percentage of inclosed cinder in the hammered bloom ranges from 10 to 15. A very important fact is that the cost of open-hearth steel will be materially reduced by the substitution of blooms for Bessemer and rail scrap, for which forty-five dollars per ton is now paid.

Based upon the cost of materials as taken from the company's books, extending over a period of one year, I have made up the following estimate:

THE ESTIMATED COST OF MANUFACTURING OPEN-HEARTH SPRING STEEL BY SUBSTITUTING SIEMENS DIRECT BLOOMS FOR BESSEMER SCRAP.

Cost of pig, castings, mill scrap, furnace scrap, spiegeleisen, and ferromanganese,	$15 58
Siemens direct blooms,	13 67
Fuel, sand, fire-clay, nozzles, sleeves, black lead, oil, moulding sand, moulds, cost of melting. (Deduction for loss and credit by pit scrap),	7 93
Cost of ingot steel,	$37 18

The results thus far obtained at Tyrone and Pittsburgh are indeed very encouraging, but they still fall far short of what Dr. Siemens has set out to accomplish. The item of coal first presents itself as one which might deter the adoption of the process at points where coal is not as cheap as at Pittsburgh. The very cheapness of the coal has probably been the cause of its lavish use. To show how nearly Dr. Siemens's ideal of one and one quarter tons of coal to one ton of blooms has been reached, I will cite the result obtained at Landore from August, 1881, to October. For these figures I am indebted to Mr. Holley:

111 charges made in 21 days 13 hours = 5.2 charges per 24 hours' continuous work.

111 tons Somorrostro ore.
66 tons 12 cwt. scale.

177 tons 12 cwt. minerals, yielding 107 tons 9 cwt. 2 qrs. blooms = 60.53 per cent. on weight of minerals charged.

24 tons 19 cwt. 2 qrs. coals for reducing.
135 tons 10 cwt. 0 qrs. coals for producers.

160 tons 9 cwt. 2 qrs. for 107 tons 9 cwt. 2 qrs. blooms = 1.49 tons of coal per ton of blooms produced.

At Landore the time for each charge has been a fraction short of 5 hours.

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Abstract of Reports of Rotator at Landore.

Date.	No. of Heats.	Charges.				Coal Delivered to Gas Producer.	Product.	
		Particulars of Charge.	Ore.	Coal for Reducing.	Scale.		Weight of Blooms.	Yield on Ore. Per cent.
1881.		Days. Hrs.	Tons.	T. C. Q.	T. C.	T. C.	T. C. Q.	
Aug. 22, 7.10 A.M., to Aug. 27, 5 P.M. . . .	28	5 10	28	6 6 0	16 16	27 10	26 4 1	58.51
Aug. 29, 3 30 A.M., to Sept. 2, 8.25 P.M. . .	23	4 17	23	5 3 2	13 16	26 0	22 6 0	60.60
Sept. 5, 7 A.M., to Sept. 8, 6 P.M.	17	3 11	17	3 16 2	10 4	23 0	16 6 2	60.00
Sept. 26, 9 A.M., to Sept. 28, 3.10 A.M. . .	13	2 18	13	2 18 2	7 16	26 0	12 16 0	61.46
Oct. 17, 6.30 A.M., to Oct. 22, 11.40 A.M. . .	30	5 5	30	6 15 0	18 0	33 0	29 16 3	62.10
		21 13	111	24 19 2	66 12	135 10	107 9 2	60.53

9th November, 1881.

Analysis of Two Samples of Spanish Iron Ore from Landore Company's Primitiva Mine. Received from Landore Company on 24th May, 1876. Analyzed by A. Willis, F.C.S.

	No. 1.	No. 2.
Iron—Peroxide,	73.420	78.500
Manganese—Oxide,	1.040	1.055
Sulphuric acid,	.077	nil.
Phosphoric acid,	trace.	trace.
Alumina,	3.000	.180
Silica,	15.680	8.860
Calcium oxide,	trace.	.380
Magnesia,	nil.	.020
Loss on ignition,	7.020	11.100
Total,	100.237	100.095

Metallic iron—No. 1, 51.394 per cent.; No. 2, 54.95 per cent.
No. 1 received 7th June, 1872, ex "Deux Menes."
No. 2 received 13th April, 1872, ex "St. Joseph."

9th November, 1881.

Analysis of Landore Scale, from Landore. Received from Towcester on 15th August, 1875. Analyzed by H. W. Le Neve Foster.

Iron—Peroxide,	36.600
Iron—Protoxide,	60.300
Sulphur,	.137
Phosphoric acid,	.058
Silica,	3.880
Total,	100.975

Metallic iron, 71.8 per cent.

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	Pounds.
	10,680
	6,125
	7,615
	4,310
	200
	28,930

JANUARY 8TH.

	Pounds.
	2,100
	6,140
	6,510
	2,500
	5,535
	5,540
	300
	300
	[illegible]

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JANUARY 9TH.

	Pounds.
Moulds,	8,240
Grafton metal,	2,460
Furnace scrap,	9,200
Direct blooms,	8,640
Spiegel,	200
Manganese,	200
Total,	28,940

JANUARY 10TH.

	Pounds.
Moulds,	8,100
Furnace scrap,	8,680
Grafton metal,	2,100
Punchings,	3,150
Direct blooms,	6,315
Spiegel,	200
Manganese,	200
Total,	28,745

JANUARY 11TH.

	Pounds.
Moulds,	6,540
Furnace scrap,	10,010
Grafton metal,	3,530
Direct blooms,	8,180
Manganese,	200
Total,	28,460

JANUARY 12TH.

	Pounds.
Wheeler metal,	4,360
Grafton metal,	5,735
Mill scrap,	5,275
Furnace scrap,	780
Direct blooms,	9,430
Iron punchings,	2,930
Manganese,	200
Total,	28,710

The following shows run of one rotator for each day while in operation since I left the works:

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Date.	No. of Heats Run.	Charges.						Product.			Remarks.
		Cleveland Ore.	Tyrone Ore.	Virginia Ore.	Total Ore.	Coal for Reducing.	Lime.	No. of Blooms.	Weight of Blooms. Per cent.	Yield.	
December 23, 1881,	90	2,500	1,000	1,000	4,500	1,400	250	17	63.0	2,870	Charged, 7.45 A.M.; Drawn, 3.10 P.M.
" 28, "	96	2,500	1,500	1,000	5,000	1,400	250	14	53.5	2,676	" 9.15 P.M.; " 6.45 A.M.
" 29, "	101	2,500	1,500	1,000	5,000	1,400	250	13	48.8	2,440	" 7.15 P.M.; " 3.05 A.M.
" 30, "	108	2,500	1,500	1,000	5,000	1,400	250	14	52.4	2,620	" 3.20 P.M.; " 9.05 P.M.
" 31, "	114	2,500	1,500	1,000	5,000	1,400	250	15	46.2	2,310	" 7.55 A.M.; " 12.40 P.M.
January 2, 1882,	120	2,500	1,500	1,000	5,000	1,400	250	15	58.4	2,924	" 6.00 P.M.; " 2.00 A.M.
" 3, "	122	2,500	1,500	1,000	5,000	1,200	250	13	47.3	2,366	" 10.50 P.M.; " 7.00 A.M.
" 4, "	126	2,500	1,500	1,000	5,000	1,300	250	11	44.4	2,220	" 9.20 P.M.; " 5.50 A.M.
" 5, "	132	3,000	1,500	1,500	6,000	1,400	300	12	51.0	3,770	" 6.20 P.M.; " 2.00 A.M.
" 6, "	136	3,000	1,500	1,500	6,000	1,400	300	15	49.3	2,962	" 11.00 A.M.; " 9.40 P.M.
" 7, "	140	3,000	1,500	1,500	6,000	1,400	300	12	42.1	2,526	" 1.55 A.M.; " 12.40 P.M.
" 9, "	142	3,000	1,500	1,500	6,000	1,400	250	19	56.6	3,040	" 1.30 A.M.; " 4.05 P.M.
" 11, "	153	3,000	1,500	1,500	6,000	1,300	300	15	43.4	2,604	" 10.00 P.M.; " 7.05 A.M.
" 12, "	160	3,000	1,500	1,500	6,000	1,300	300	14	46.2	2,770	" 9.00 P.M.; " 5.00 A.M.
" 13, "	165	3,000	1,500	1,500	6,000	1,300	300	15	46.7	2,805	" 12.30 P.M.; " 4.40 A.M.
" 14, "	170	3,000	1,500	1,500	6,000	1,300	300	12	43.3	2,600	" 4.00 A.M.; " 12.20 P.M.
									49.0	43,503	

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DISCUSSION.

DR. EGLESTON, New York city: Do I understand that the proprietors of the Siemens-Anderson process do not intend to manufacture merchant iron, but only blooms to be used in some open-hearth process?

MR. MAYNARD: Yes.

DR. EGLESTON: If that is so, and it is understood that this process is to be used not for the manufacture of merchant irons, but only for the purpose of making material similar to iron sponge, to be treated afterwards in an open-hearth furnace, I see no reason why this direct process should not be successful. The difficulty with all direct processes has been not that iron cannot be made from the ore, but that the products contain so much oxide of iron and other impurities that they require to be sunk in a bath, on a principle similar to the pig and ore, or the pig and scrap process of the open-hearth furnace.

The question of phosphorus in these products is merely a question of temperature. Berthier showed, in 1837, that nearly all the phosphorus in iron can be eliminated if the slags are removed in the puddling furnace before the welding heat necessary to get the iron into a ball is reached; but if the temperature is raised high enough to make the balls, the phosphorus goes out of the slag into the iron. This principle has recently been applied to the manufacture of merchant irons from poor pig, the slag being removed from the furnace and replaced by pure slag. A similar thing was done some years ago in a blast furnace, at Buffalo, working on ores that contained a large amount of phosphate of lime. The furnace was made to work so cold that the whole of the phosphate of lime went into the slag, and not into the iron; the moment the attempt was made to make gray iron, the phosphorus went into the iron, and not into the slag.

WILLIAM METCALF, Pittsburgh, Pa.: I must declare myself a heretic on the whole subject of so-called direct processes. Having experimented largely, and at a large cost, in both the Siemens and the Dupuy direct processes, I have to say that the chemical result was always good, and the commercial result was always bad; and I have come back to my original opinion that there is no process more direct and simple, with assured commercial results, than that of the blast furnace and the Bessemer converter.

The most important admission made in the paper of Professor Maynard, and in the discussion, is that the product of these direct processes can not be used as wrought iron. This admission clears

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away a great deal of mist, and, if heeded, may save further experimenters much disappointment and heavy losses. The reason the material will not answer for commercial wrought iron is that it is always full of oxygen and is too red-short to be worked. This is a matter that can be corrected easily in steel making, but it cannot be cured economically, if at all, in the making of wrought iron.

Mr. Holley, with his clear insight into such matters, saw this years ago, and settled down to the opinion that the process might be made valuable as an adjunct of the open-hearth process, and that that was its only value.

I must say I am still skeptical even upon this point, and the facts given in the paper are not sufficient to base an opinion upon; we want longer runs, covering a year or more of regular hard work, with accurate records of the consumption of material, and of the amount and cost of output. There is much machinery about these furnaces, and it must be tested by hard running before we can estimate its value, and then we must compare the cost of plant, repairs, wear and tear, labor, etc., for each ton of output, with the same items by the old process, before it will be safe to announce success.

The paper states that steel can be made by this process with two tons of coal per ton of steel. We can do, and are doing regularly, year in and year out, about as well as this by the most (so-called) indirect process, namely, through the blast furnace, puddling furnace, and crucible. Here are the figures, taken from records kept with great care, and running over years of steady working:

Fuel used per ton of pig iron, ...	2240 pounds
Fuel used per ton of muck iron, ...	1216 "
Fuel used per ton of crucible steel, ...	1120 "
Total for the three processes, ...	4576 "

These are no fancy figures; with ordinary care the work can be done within these limits every day in the year.

Now as to quality: Mr. Holley has shown that by the use of the Danks-Bouvard puddling furnace, iron can be made containing 0.082 per cent. of phosphorus from pig containing 0.815 per cent. of that substance; also irons with 0.004, and less than 0.007 per cent. of phosphorus from pigs containing, respectively, 0.04 and 0.07 per cent. Further, this iron has good commercial qualities, and has been made by thousands of tons, with a consumption of 1,161 pounds of coal per ton of 2240 pounds of iron. Mr. Wellman, of Cleveland, saw this

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process at work and brought to Cleveland a lot of pig iron and about ten tons of blooms. He analyzed the pig, and also analyzed every bloom of the lot separately, and found Mr. Holley's report to be correct without exception. If anything more were desired, the addition of the Bell-Krupp washing process would result in eliminating phosphorus absolutely.

What we need now, to convince us that this direct process has any value at all, even for open-hearth practice, is the erection of a plant capable of producing 100 to 200 tons a day; that plant should be run to its full capacity for a year, and its output and cost should be compared with the Creusot practice, the Eston practice, or American Bessemer work; thus we should know which process is most direct, cheapest, and most reliable in quality.

As to the loss of iron: in the blast furnace there is no loss; in puddling there is a loss of about 8 per cent., and in the crucible there is no loss; in the Bessemer process the loss is a little heavier than in puddling, and in these direct processes the loss varies from 20 to 50 or even to 100 per cent., according to the luck in working. The only possible way to avoid very heavy losses is to have an open-hearth bath always ready to receive the balls as soon as they are formed.

So far, practice has proven that the cheapest, safest, and most direct process begins at the top of the blast furnace.

HENRY M. HOWE, Troy, New York: In spite of its commercial failure I still believe that Blair's is the best direct process yet offered, at least in places where ore is comparatively dear and coal comparatively cheap, such as Pittsburgh. The protection against loss from oxidation of the sponge, by allowing it to cool completely in a highly reducing atmosphere, appears to me more complete than in any other direct process. When the process was being worked, the loss, which was about 15 per cent., was not greater than it then was in the best open-hearth works which were using blooms. What the process needed more than anything else was a more rapid method of cooling the sponge. This I think could have been done in about half the time actually taken, and the output of each furnace could thus have been greatly increased. With proper management I do not believe the furnace would have failed.

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VALUATION OF IRON MINES IN NEW YORK AND NEW JERSEY.

BY PROFESSOR JOHN C. SMOCK, ASSISTANT GEOLOGIST OF NEW JERSEY, NEW BRUNSWICK, N. J.

THE question of the proper valuation of mines of iron ore was suggested to me by the difficulties experienced in getting answers for the United States Census Office, while I was engaged in the work of collecting the statistics of mines in New Jersey and New York. The answers to the questions relating to values of real estate of mine properties varied so greatly that it was necessary to revise them according to some general principles of valuation. Generally the returns of mine proprietors seemed to be too low. There were, however, examples of what would be termed excessive valuation. The subject appeared to be of practical importance, and led to the paper here presented.

The following table of selected mine statistics is given, prefacing the discussion of the principles of valuation. It is in part made up of census returns and partly of data obtained directly from mine owners and managers. The mines which were selected for the several groups and mining districts include nearly all of those from which the more full and carefully filled returns were received, and are also representative of their respective districts. Hence the averages obtained from them become good types of these groups or districts. The mines of New Jersey appear in six groups, each containing from three to eleven mines, or, in all, thirty-four mines. The magnetic iron ores of New York are in four well-marked groups, and there are twenty-six mines in them. Then follow the red hematite mines of St. Lawrence and Jefferson counties; and, lastly, the brown hematite groups of Dutchess and Columbia counties, and those of the adjacent parts of Connecticut and Massachusetts. The whole number of mines represented by the table is eighty-eight, of which twenty-eight are hematite mines. The first column gives the value of the real estate; the second that of the plant; the third is the sum of these two, or the capital invested. Then follow the number of men employed, the amount of wages paid during the census year, and the value of materials used in mining and preparing the ores for market.* The seventh column gives the total expendi-

* The value of materials is somewhat uncertain in many cases, as royalties are included under this head. Likewise, under wages, the cost of explosives and light is often included. Hence it is impossible to draw the line sharply between these items of expenditure.

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tures, or cost of the ore. The product in tons is in the eighth column, while the cost per ton is in the ninth. The last column of the table shows the ratio between the real estate value and the product.

TABLE OF SELECTED STATISTICS OF IRON MINES.

	MINING DISTRICTS AND GROUPS OF MINES.	Capital invested in real estate.	Capital invested in plant.	Total invested capital.	Number of men employed.	Amount of wages.	Value of materials used.	Total amount expended.	Tons of ore mined.	Cost per ton of ore.	Total capital in real estate per ton of ore mined.
I.	Warren Co., N. J.,	$273,200	$72,104	$345,304	411	$118,751	$23,902	$142,653	43,607	$3.27	$6.27
II.	Sussex Co., and western part of Morris Co., N. J.,	295,000	71,000	366,000	374	138,438	53,511	191,949	85,595	2.24	3.44
III.	Chester, Morris Co., N. J., . . .	250,000	40,290	290,290	233	66,147	16,152	82,299	40,460	2.03	6.18
IV.	Mine Hill—Irondale Range, Morris Co., N. J.,	710,000	174,300	884,300	972	365,083	104,506	469,589	117,035	4.01	6.07
V.	Mt Pleasant—Mt. Hope Range, Morris Co., N. J ,	540,000	152,000	692,000	639	300,990	125,093	426,083	125,685	3.39	4.29
VI.	Northern part of Morris Co., N. J.,	925,000	129,770	1,054,770	1,017	425,314	161,009	586,323	147,958	3.96	6.25
	New Jersey Mines,	$2,993,200	$639,464	$3,632,664	3,646	$1,414,723	$484,173	$1,898,896	560,340	3.38	5.34
VII.	Orange Co., N. Y.,	805,000	62,300	867,300	383	130,814	37,960	168,774	77,001	2.19	10.45
VIII.	Putnam Co., N.Y.,	522,030	44,805	566,835	434	165,465	46,000	211,465	66,800	3.16	7.81
IX.	Essex Co., N. Y., .	1,474,377	505,595	1,979,972	1,268	457,223	242,052	799,275	506,843	1.57	2.91
X.	Clinton Co., N. Y.,	375,000	115,500	490,500	699	190,870	38,800	229,670	80,645	2.84	4.65
XI.	*Red Hematite.* St. Lawrence and Jefferson Counties, N. Y., . .	358,000	102,000	460,000	366	152,689	28,500	181,189	84,374	2.15	4.24
XII.	*Hematite.* Dutchess and Columbia Counties, N. Y., . .	966,049	208,000	1,174,049	593	181,087	68,945	250,032	124,957	2.00	7.73
XIII.	*Hematite.* Connecticut, . .	381,000	33,500	414,500	180	60,667	20,553	81,220	31,141	2.61	12.23
XIV.	*Hematite.* Berkshire, Mass.,	157,000	59,000	216,000	311	109,121	41,792	150,913	49,454	3.05	3.17

NOTE.—The tons are 2240 pounds.

The first observation to be made on this table is suggested by the discrepancies that are apparent when capital and product are compared, as is done in the last column. The differences in the ratios of product to capital are greatest in the groups of magnetic iron ore mines of New York and the hematite mines of Connecticut and Massachusetts. In the latter State, $3.17 of real estate produced a

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ton of ore, whereas, in Connecticut, it required an investment valued at $12.23, or nearly four times as much. Although much of this difference is inherent in the mines, and due to great disparity in actual value, some part of it must be credited to imperfect valuation, and a more accurate method of valuation would tend to the equalization of these ratios. Another observation to be made is the variation in the cost of the ore per ton, ranging from $4.01 to $1.57. The greater cost is found to be in the groups of deeper mines. The larger proportion of open workings or pit work reduces the average cost. The larger size of the ore bodies also lessens the cost; and the more expensive the plant, when compared with the total expenditures, the less is the cost of the ore. And, in general, the labor expenditure seems to enter more into the cost than the value of materials used, although the separation of these classes of expenses is nearly always incomplete. Other points for consideration and comparison will suggest themselves to the reader who may examine the table.

The elements which enter into the problem of valuation are many and diverse. Some of the principal factors are capacity, accessibility, ease of mining, facilities for working, nearness to transportation lines, cost of labor and materials, and demand for the ores. They might be summarized as accidents of place and time. Hoskold, in his *Engineers' Valuing Assistant*, says: "A rule cannot be laid down expressing the attendant risk of mining adventure, as nearly all mines exist under circumstances differing widely from each other. It is a matter of experiment; each mine must, therefore, stand upon its own merits." While this statement must be accepted as eminently wise and cautious, still, in the valuation of mines, it is necessary and desirable always to learn something of the history of the mines in any given district in which we may be required to put values upon new or but partially developed localities, and also to study their statistics. Their success or failure must, to a certain extent, guide us in new ventures. And these features are quite as important to know as are the geological relations and modes of occurrence of the ores to be won. Hence it is that the characteristic features of any mining district become at length apparent in the working statistics, and such statistics, when properly studied, indicate capacity, extent, facilities in working, etc. And, therefore, almost the first question regarding any mine is what of its surroundings, not only so far as concerns the association of ore and rocks, but also the results of mining enterprises in the neighborhood or district.

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Having examined them and ascertained the characteristics, it will be prudent to keep in mind that they are not to be reversed in any new undertaking, without extraordinary skill and energy in management or a fortunate concurrence of favoring conditions.

The further examination of localities, with a view to their proper valuation, must note the extent of ore-body, the probable capacity of production, and the length of profitable working period. These inquiries involve the study of the structure, depth of ore beneath the surface, nature of the ore, the facilities for exploitation and mining, the cost of labor, materials, etc., the accessibility to lines of transportation, and the extent of the demand, together with prices. To go into the discussion of all these elements would exceed the limits of this paper, and only a few generalizations can be given, which may be accepted to a limited extent as safe guides. The enduring character of our iron mines in New Jersey and in New York is here to be noted, as it bears so closely upon this question of their value; it is particularly true of the magnetic iron ore mines. Many of them have been worked steadily for long periods, and some of them figure in our colonial history. Their production previous to 1840 was comparatively small, and the larger part of the aggregate amounts obtained from them belongs to the past three decades. Notwithstanding the extent to which they have been opened, there are no signs of exhaustion. It seems entirely safe to assert that many of these ore bodies, now so largely explored, are practically inexhaustible, at least by known methods of profitable mining. They are an enduring species of property. There are, however, examples of exhaustion and abandonment, as well as many cases of temporary suspension, owing to causes outside of capacity for producing ore in quantity. Out of the list of one hundred and fifteen mines given in the *Geology of New Jersey*, published in 1868, twenty-five had been abandoned before 1881. In the period from 1867 to 1882, twenty-five others had been started into activity and run their course, making together fifty suspensions in that period. Of the old mines which had been abandoned, the working periods ran back from ten to one hundred and sixty years. It would not be possible to arrive at any very reliable average between so wide extremes. In the same fifteen-year period thirty new and productive mines had been opened in the State, and contributed largely to its total product. That some of these abandoned localities may again be worked cannot be doubted. From these general statistics it is evident that no definite term can be assigned as probable for the

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working history of any mine. And what is true of New Jersey applies with equal force to New York, especially to the mines of Orange and Putnam counties. In this connection it must be stated that the numerous smaller ore openings have been omitted, as not belonging to the class of *producing mines*. In order, therefore, to arrive at some fair average period of productiveness, recourse was had to the total production of many representative mines and its comparison with the output for the census year. In the case of all the older mines this total product is a rough estimate at best. It is approximately correct in the mines opened within the past thirty or forty years. Now, assuming the rate of the census year (in many respects a good representative of our working mines), it is easy to ascertain how long it would have taken to raise the total amounts estimated as coming from them. From fifteen to thirty-five years would have sufficed in all of our larger mines, both in New Jersey and in New York; in others, from four to ten years. The average for safety may be put at fifteen years, as applicable to the mines now vigorously worked, and also to those newly opened, which promise to do quite as well.

Having assumed the working term and the annual product the remaining essential factor in all cases is the profit per ton. This was obtained by subtracting the cost from the average price at the mine in the several districts, as follows:

	Average price.	Cost.	
New Jersey mines,	$4.16	$3.38	$ .78
Orange County, N. Y.,	3.00	2.19	.81
Putnam County, N. Y.,	3.00	3.16	-.16
Essex County, N. Y.,	3.30	1.57	1.73
Clinton County, N. Y.,	4.50*	2.84	1.66
St. Lawrence and Jefferson counties, N. Y.,	2.70	2.15	.55
Dutchess and Columbia counties, N. Y.,	3.90	2.00	1.90
Connecticut mines,	4.80	2.61	2.19
Massachusetts mines,	4.00	3.05	.95

These elements are sufficient to give the basis for valuations, so far as the several districts are concerned. The problem is in the nature of an annuity, and knowing the term and amount received annually the question is, what is it worth? In the case of the New Jersey mines the value of the real estate was placed at seven times the annual dividend or amount of profits. Thus, for example, taking the thirty-four mines in New Jersey, according to the table

* The high price of these ores is due to the amount of separated ore for forge use.

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above, their product was 560,340 tons, which at 78 cents per ton, would yield a dividend of $437,065.20, and that multiplied by seven gives $3,059,456.40, as their valuation. It remains to fix the rate of interest and to allow for a return of the investment, or what is known as a redemption fund. Authorities differ so widely that it is almost an arbitrary matter to assign any figure. The mean range is from 8 to 20 per cent. The rate allowable for redeeming the principal should not exceed 4 per cent.,—that of our most reliable trust-fund investments. Owing to the great permanency which characterizes many of our iron-mine properties, 10 per cent. has been thought to be a reasonable profit upon the capital, and 4 per cent. sufficient for its redemption. Turning to Hoskold's tables we find that the present value of $1 per annum in fifteen years, allowing interest at 10 per cent. upon the purchase-money, and redeeming the capital at 4 per cent., is $6.669, or nearly the arbitrary multiplier which was used in the case of the New Jersey mines. With a higher rate of interest, *e. g.*, 20 per cent., the multiplier would be 3.061. These are the general principles which have been employed in the valuation of nearly all of the mines of New Jersey and in many of New York. As already stated they are subject to almost endless modification, owing to the ever-varying combinations of the other essential elements, which need to be taken into account and which vary with almost every mine.

THE NEW MILL AT BATOPILAS, STATE OF CHIHUAHUA, MEXICO.

BY JOHN C. F. RANDOLPH, E.M., NEW YORK.

THIS mill being now in successful work, it seems proper to record some professional memoranda concerning it. It is intended to handle an unusual ore, in a locality difficult of access, and its arrangement and method of procedure present some novel features of interest.

It was prepared for the San Miguel property at Batopilas, State of Chihuahua, Mexico, owned by the Consolidated Batopilas Silver Mining Company of New York, at present under the management of ex-Governor Alexander R. Shepherd. This property contains a large series of more or less parallel veins, worked through a deep cross-cut tunnel 1300 feet in length. The vein rock of these veins is calcspar in diorite. While, near the surface, ruby silver, black

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viz., the Silver Islet mine of Thunder Bay, Lake Superior, Canada. The mill erected there, however, represents very different conditions and very different material. At Silver Islet the silver is invariably in the form of complicated alloys with cobalt, nickel, and other metals, as represented by the new minerals huntilite, animikite, and macfarlandite. In Batopilas the silver is pure crystallized silver, and no alloy of any kind has ever been detected in it. Since the metallurgy of the complicated alloys of Silver Islet was exceedingly difficult, needing the use of furnaces and cheap fuel, and since the locality itself was not favorable for these operations, the problem in constructing a mill there resolved itself into a concentrating operation in *loco*, with the intention of transporting the rich concentrates produced to a point more favorable for reduction. The reduction has in effect always been carried on at Detroit, Michigan. The mill at Silver Islet consists solely of stamps and Frue vanners, and offers little assistance for the solution of the problem at Batopilas; and even were it of the class desired, it is not sufficiently well designed to be a model.

At Batopilas, the reduction must be complete, and the only method allowable is one where the ore shall enter the mill at one end and the silver bars shall leave it at the other. To this course the ore itself presents no special difficulties of metallurgy, and the only obstacles to carrying it out effectively in the large way are those offered by the topography of the country, which makes the transportation of machinery difficult. Batopilas is some 300 miles from the Gulf of California, in the southwest corner of the State of Chihuahua, and is the same distance from the city of Chihuahua to the east. The only transportation possible is by mule back, between the limits of 150 pounds for side packages, and 280 pounds for back packages. The country is exceedingly rough and precipitous, and the sectionalizing of machinery for transportation in such small packages, which, when erected, should be unimpaired in efficiency, stability, and value, offered in itself a problem of no ordinary difficulty. The peculiar ore to be handled, the utter lack of guiding experience with similar ores, and the absolute necessity of shipping only bar metal, made it incumbent that this mill should be very carefully designed, and not merely be an effective plant for one method and one class of material, but that it should allow the widest variations both as to procedure and as to material treated. The intention was, therefore, to design a wet silver mill of great *flexibility* and power of adaptation, so that the most effective and economical method of treating all occurring ores

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might be arrived at without any radical alterations of the original construction.

Since the ore to be treated of the native-silver class admits equally well of pan amalgamation or concentration, and since all of the other occurring ores could undoubtedly be effectively treated by concentration with or without a subsequent roasting before amalgamation, the plan of the mill seizes on both these methods and combines them so as to operate them either singly or together at the same time for different batteries. This seemed the more desirable since, although the native-silver ore is equally amenable to either pan amalgamation or concentration, it is by no means certain which method will give the most economical and satisfactory results in that locality until they are brought down to comparative figures on the same ore. For the same reason the mill has been erected as a steam mill, with the intention of connecting it with the existing water-power at a later date, in order to allow of the fullest flexibility as to power.

The mill is a 15-stamp mill with place for 20 stamps. (See accompanying plates.) It is built on a side hill behind the old Hacienda de Beneficio, and consists of six steps, the lowest of which is in the yard of the present hacienda. The first step consists of the ore floor, on which the ore is delivered from the tramway, constructed simultaneously with the mill and for the purpose of supplying it. This tramway is one mile long, and crosses many arroyos and gulches on arches of masonry. It was a most expensive construction on account of the difficult topography. The first plan was to build an overhead tramway of the wire-rope type, but the exigencies of mule-back transportation made the transportation of long cables difficult and undesirable. The ore before leaving the mine yard is cobbed and sorted, in order to separate any high-class ore from it. It therefore arrives on the ore floor properly sized for the stamps without the intervention of a jaw crusher, the transportation of which, in even well-sectionalized form, would be difficult. The ore is bulk-headed on the ore floor back of the stamps, and shovelled to the Challenge self-feeders, one of which belongs to each battery. On the second step are the self-feeders and the batteries. The stamps are 650-pound stamps, with 10-foot stems, 3 inches in diameter, and provided with Coleman's patent tappet. The stamps are throughout of the California type, with high mortars and separate cam shafts. While some coarse silver will remain in the batteries, the majority of it will pass the screens as a pulp. From the screens branch the pulp-launders, which, uniting together below, form one main launder and conduct the stamped ore

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to the pulp-boxes on the fourth step. Beneath these launders on the third step are four Frue vanners, with distributing launders at right angles. By means of gates and plugs, the pulp from any individual battery, or from all of them, can be stopped in its course to the pulp-boxes and at once diverted to the necessary Frue vanners. By this means an immediate change of operation for the whole mill, or for any desired battery, can be effected at a moment's notice. The pulp-boxes on the fourth step are 12 in number, and are built of solid masonry, plastered inside, since the usual wooden pulp-boxes soon become useless in a tropical climate. On the pulp-boxes there is a track, provided with turn-tables, by means of which the pulp is transferred by a car from the box that is being dug out, to the pan to be charged. The fifth step is devoted to the amalgamating apparatus, which consists of six 4-foot combination pans, with cast-iron bottoms and wrought-iron sides, three 7-foot settlers of like construction, one 4-foot clean-up pan, two small laboratory pans, a mercury safe, and a travelling hoist above the pans. A small Sturtevant blower also takes power on this step for the blast to the cupellation furnace. The sixth and last step of the mill contains an English cupellation furnace, a retort furnace of four retorts, pot furnaces, and office. On the same step with the pans, but in a separate building, there are two tubular boilers, 42 inches by 14 feet; and on the same step with the vanners are two horizontal engines, with 10-inch by 20-inch cylinders, connecting separably, by clutches, to a common band pulley. The water for the mill is pumped by a Deane steam-pump to a reservoir above the stamps (not shown in the drawing). It is proposed when the mill has got into such steady practice, with the use of steam, as to make it proper to throw out of work the machinery driven by the existing water-power, to make such alterations of the ditch and turbines as will allow the connection of the main pan-shaft of the mill with the turbines by means of wire-rope transmission, and by this means to insure the fullest command of ample power at all seasons of the year.

The main objects, therefore, held in view for the San Miguel mill were (1), to erect a mill which would interfere as little as possible during construction, with the existing business of the hacienda; (2), to design it for the largest variations in process and class of material, with the use of but one well-arranged plant (for a new locality, difficult of access, and an ore never before handled by machinery, the largest freedom for experiment and comparison was deemed vital); (3), to give it the largest means of power, so that in the wet season,

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when water is abundant, and dry wood scarce, the mill can be driven by water-power, and, on the contrary, in the dry season, when these conditions are more or less reversed, steam-power can be used. The Batopilas River carries so abundant a supply of water throughout the year that in all probability the eventual practice will be entirely by water-power the whole year, except at times of accident to the water-power, when steam will promptly replace it. There may undoubtedly be times when, owing to great drought or leakage of the ditch, the water-power will not be ample, and in this event the mill will be driven temporarily part by water-power and part by steam-power, a possibility contemplated in the design.

To insure an increase of production during the erection of the mill, a small plant of 5 stamps, 2 pans, 1 settler, 1 Frue vanner, and 2 turbines, was sent down with the other machinery for temporary use in the yard. The intention was to continue working the 3 arrastres up to the moment of the erection of this temporary plant, and then to cut them off from the water-power and throw the power on the machinery. This was done almost in the manner planned, and the arrastres were given up some months since. In the same way, the plan was, on the completion of the 15-stamp mill, to throw it into work by steam-power, and then, moving the temporary 5-stamp mill to its proper place (increasing the effective strength of the mill to 20 stamps), at once to make such changes of the water-power as would allow the 20-stamp mill to be driven entirely by water-power, with the engines and boilers in place simply as a supplementary plant for accidents and emergencies.

The rationale of the method of handling the ore will be readily seen. The ores which can arise on the San Miguel property and in the district are:

A. *Surface Ores.*—Chlorides, light ruby silver, dark ruby silver, stephanite, and freieslebenite (never found to a greater depth than 200 feet, and in many veins entirely wanting).

B. *Ores Below* 200 *feet.*—Massive silver (unusual); *brosa silver* ($\frac{2}{3}$ silver, $\frac{1}{3}$ calcspar); *chispeado silver* ($\frac{1}{3}$ silver, $\frac{2}{3}$ calcspar); *clavo silver*, up to 800 ounces to the ton; *azogues*, amalgamating ores, 40 to 200 ounces.

Of class A, none are as yet known on the San Miguel property, since all the workings are from a deep cross-cut tunnel. As some of the workings are now 300 feet above the tunnel, and daily advancing upward, these ores may at any time arise for beneficiation. Other properties in the district, of which the workings are still

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shallow, are producing more or less of these ores, and a handsome profit can at any time be made on their purchase.

The main ore of the district is shown in class B, of which only the massive solid silver is unusual. Since the mill is designed mainly for these ores the procedure with them will be first spoken of.

I. The brosa and chispeado ores will be stamped either wet or dry (in the latter case with a horizontal screen) for the obtaining of *stamp silver*. If stamped wet, the operation will be in one of the batteries of the main mill, through a screen, sending the pulp by the launders at will either to concentration or pan amalgamation. If stamped dry, it will be done by a 3-stamp Nova Scotia battery, with open front and horizontal screen (not shown in the drawing), which has figured prominently in this operation in the past history of the property. In either event, the stamp silver will go to scorification with lead (as in the past), or direct smelting, with lead or galena, in a cupola, if this is found preferable, and then to cupellation. In case of smelting in a cupola, the stamp silver would need a quartzose flux for the calcspar, while, in scorification, the carrying off of the calcspar is purely mechanical by means of the litharge, and gives rather heavy losses in lead and silver.

II. The clavo and azogues ores are the main *raison d'être* of the mill under discussion. They run from 40 to 800 ounces in native silver. While the clavo ores (containing nails and tacks of silver sparsely sprinkled in them) are greater than the brosa and chispeado in amount, they are far less in amount than the azogues, or amalgamating ores, with which brosa, chispeado, and clavo silver are surrounded. These two classes of ore being fed by the Challenge feeders to the several batteries, pass through the screens to the launders, and the pulp goes directly to amalgamation, or to concentration, since these ores can with equal facility be either amalgamated or concentrated.

In case of amalgamation every two pans empty into one settler, and the amalgam discharges continuously from the settler by cup-and-siphon connection to the amalgam safe, in which it is strained. The amalgam goes from the strainer to the washing-pan, and it is hoped that by this mechanical washer the amalgam can be thoroughly freed from pyrite, mispickel, and blende, and that the retort silver will be very fine. The old practice with the arrastres, where the amalgam was washed by hand, gave a retort so full of blende and pyrites as to necessitate cupellation of the retort silver in order to produce fine bars.

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In case these classes of ore go to concentration, the tailings, if valuable, will go to the pulp-boxes, and the concentrates be treated either by adding them directly to the charge in the pans, or they can be added directly to the charge of stamp silver in scorification. In stamping these classes of ore some stamp silver will undoubtedly accumulate in the mortars, consisting of spikes, nails, and tacks, which cannot pass the screens. This will be removed periodically, according to its amount, and added either to the pan-charge or to the scorification-charge. The mill can, as shown, work these ores at any time, entirely by amalgamation, entirely by concentration, or in part by amalgamation and in part by concentration.

III. The ores of class A, or surface ores, although never great in quantity, will be continually arising, either from this property or by purchase. Can this mill handle them? The chloride ores can be treated as though they were native silver ores, and be stamped with them for the pulp-boxes and amalgamation. The ruby silvers, the black silvers, the freieslebenite, dufrenoysite, etc., when arising in sufficient quantity to warrant it, can be confined to one battery, and the pulp from this battery can go to the vanners for concentration. In such concentration 70 per cent. of the black silver and freieslebenite would be obtained, but probably not more than 40 per cent. of the ruby silver. These concentrates would be roasted and then subjected to amalgamation, or direct reduction with lead, and the tailings would go to special pulp-boxes for treatment, in a special pan or series of pans, either alone or with a large preponderance of native-silver pulp, and the use of chemicals. In this way, it is believed that an excellent percentage of value can be taken out of such small quantities of base ore as arise, although it is not assumed for a moment that nearly as good results with some of them (*e. g.*, ruby silver) can be attained, as with a dry mill especially adapted for them. They are, however, only accidental ores of small quantity, from which this mill can obtain far larger profit in the manner designated, than has hitherto been possible.

A few words as to methods of sectionalizing a mill of this description. The *stamp-stems* are 10 feet long and 3 inches in diameter, bevelled at either end; the weight of each is about 230 pounds, and though a load of inconvenient shape, one was easily carried by a mule, with some other weight in addition. The *mortars* needed special care in designing, not merely that they should fulfil the conditions of mule-back transportation, but that they should be really effective tools when assembled. They are 52 inches long with 9½

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inches between stems. The bottom of each is made in five pieces, dovetailed together, with tooled surfaces rendered perfectly tight with a rust-joint. The housing of each is boiler-iron, cut, fitted, and punched before shipment, and joining the cast-iron bed by dovetails, rust-joints, and bolts, so as to be absolutely water-tight. Each mortar is provided with cast-iron lining-plates, sectionalized, so that the wear shall not come on the housing. The *pans and settlers* have sectionalized cast-iron bottoms, dovetailed, rust-jointed, and bolted, and boiler-plate housings, sectional mullers, dies, and lining-plates. The *shafting* was all shipped in lengths of 6 to 10 feet. The *pulleys* were shipped in the form of cast-iron hubs, to be built up in wood to the proper size. The *boilers* were shipped as formed, punched, and marked plates, boiler-tubes, etc., and had been carefully assembled before shipping. The stacks were sent forward as punched and formed plates. The *engines* and fly-wheels were not of a size to offer difficulty in sectionalizing. All of this material was sectionalized successfully between the limits of 150 pounds for side packages and 280 pounds for back packages, and, to the credit of the Fulton Foundry, San Francisco, not a single package was found too heavy for mule-transportation, either of the 70 tons comprising this mill, or of some 40 tons additional of like machinery for two smaller mills, designed and sent on at the same time. This machinery was transported from San Francisco by steamer to Guaymas, Sonora, then reshipped by schooner to Agiobampo, 300 miles southward, between Mazatlan and Guaymas. From Agiobampo it was carried forward by mules in relays. The first relay consisted of Tierra Caliente mules, unaccustomed to the mountains, carrying their freight as far as El Fuerte. The second relay took the freight partly into the foothills of the Sierra Madre, and the third relay, consisting entirely of mountain mules, carried the freight over the mountain trails to Batopilas.

The cost of the 15-stamp mill complete, as delivered from the shop, was $17,000, and it was shipped from San Francisco, January 10th, 1881. The extraordinary floods of an early rainy season, and other causes of a purely tropical character, delayed the completion of the mill until December, 1881. That it will have a great history there is but little doubt, as the property is a remarkable one, and the ore developed for the mill during its construction is said to amount to its capacity for three or four years ahead. The mill is designed to run 2 tons to the stamp per 24 hours, and it will, not improbably, do better duty with these calcspar ores. Fifteen to twenty stamps

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were selected as the best experimental medium, and while subseq mills in this locality will undoubtedly differ in some particulars f the mill of San Miguel, this mill will give facts and figures means of which a more perfect mill, if needed, can be designed a sure hand.

This mill was planned with the professional co-operation of John Magnus Adams, of San Francisco, a member of this Instit to whose thorough knowledge of milling it owes many valu points, especially as to the novel position of the Frue vanners. supervision of the work while under construction in the shop, and shipping of the finished plant, were also intrusted to this gentlem It was erected under the supervision of Mr. Walter M. Br a member of this Institute, late Superintendent of the Minas Nue Alamos, Sonora.

NOTE ON MANGANESE IN BESSEMER RAIL-STEEL

BY JOHN W. CABOT, JOHNSTOWN, PA.

THE following series of analyses, which may be of interes Bessemer-steel makers, is submitted as a contribution to the m vexed discussion of manganese in Bessemer steel. They were m by the writer in the spring of 1881, at the works of the Pittsb Bessemer Steel Company Limited, during a period of about e days, part of which time the rail-steel showed great variatio rolling qualities.

During the first part of the time in question, it rolled w later on it began to roll worse until, finally, it cracked very ba reaching its worst stage. After this it rapidly improved unt again rolled smoothly. During this time of transition from g rolling to bad, and back to good again, the course of the manga was followed quite closely. It is the striking correspondence tween these varying manganese contents and the differences in rol which is here presented as worthy of notice. The other ordi elements were determined occasionally, but showed no unusual v ation. The steel, in question, was ordinary rail-steel of about following composition:

C = .35. P = .08. Mn = .98. Si = .08. S = .05.

The samples for manganese determinations were taken at from an average of two days' work, and later on, when the

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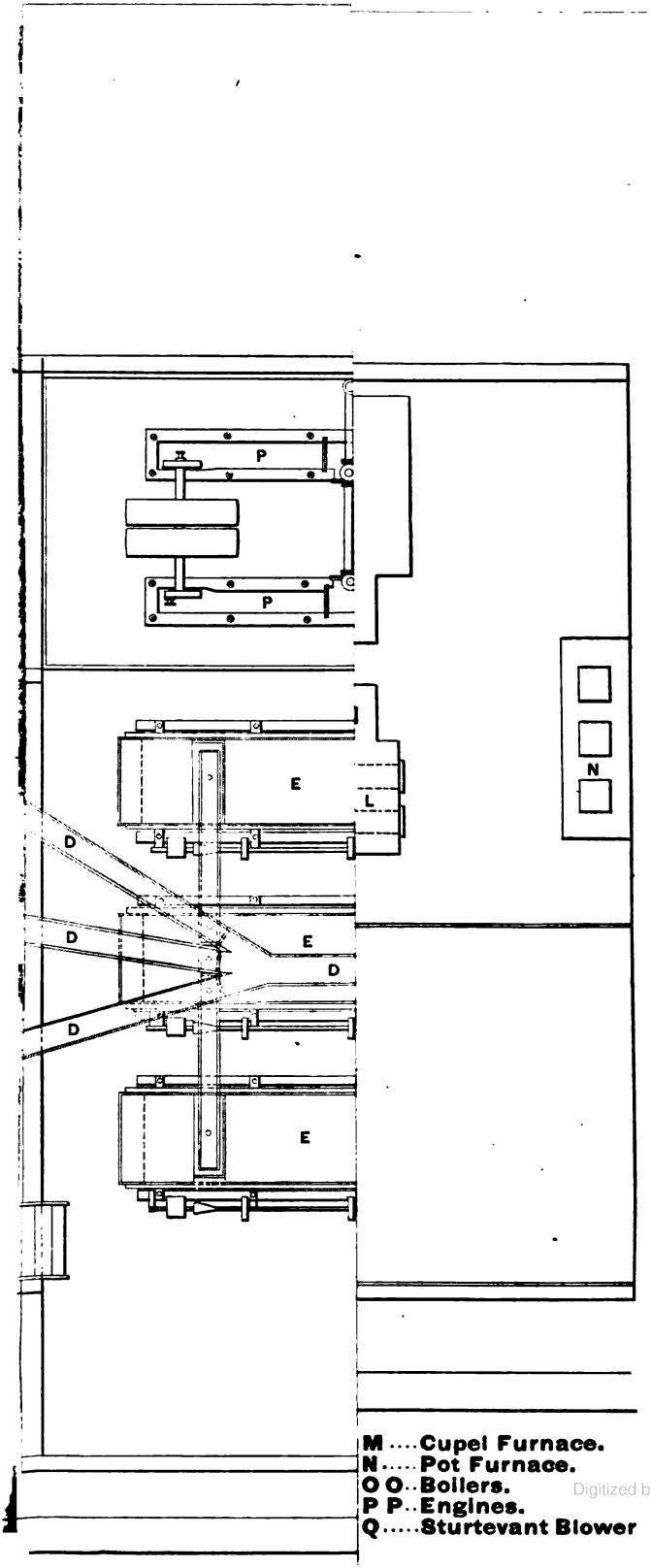

M ....Cupel Furnace.
N.....Pot Furnace.
O O..Boilers.
P P..Engines.
Q.....Sturtevant Blower

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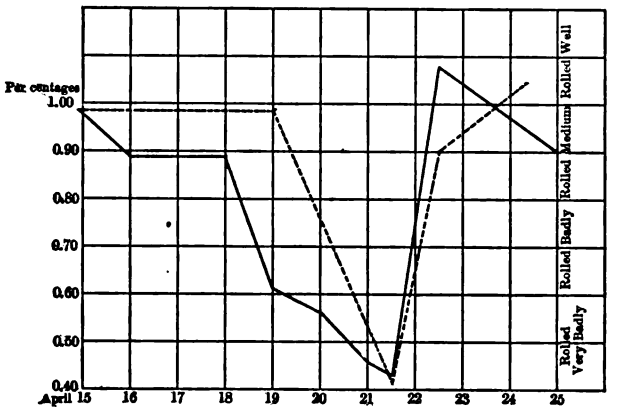
rolled badly, from single blows, which were considered fairly to represent the condition of the steel at the time. In regard to the mechanical condition and treatment of the steel, it was made just as usual, even more care being taken with the mixtures, the heat at the vessel, the casting, and every detail of manufacture likely to affect its rolling; while, in the blooming-mill, extraordinary pains were, of course, taken with the heating and rolling.

Following is a tabulated statement of the manganese percentages, with corresponding observations on the rolling qualities of the steel, and also the dates on which samples were taken.

Date.	Manganese.	Steel rolled
April 14th and 15th.....	.98	Well.
" 16th and 18th.....	.89	Well.
" 19th.....	.62	Medium.
" 20th.....	.57	Badly.
" 21st.....	.46	Badly.
" 21st.....	.43	Very badly.
" 22d.....	.75	Medium.
" 22d.....	1.08	Well.

A curve is also given in the accompanying diagram drawn with manganese percentages, as ordinates and days on which they were determined as abscissæ, each large vertical space representing .1 per



cent. of manganese, the horizontal distances being days. For comparison with this, an approximate curve of rolling is shown in dotted lines, being plotted with horizontal distances as days, as before, and

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vertical spaces representing the rolling of the steel from "wel
"very badly."

In this series of results the manganese was apparently the
element, either in the chemical composition or mechanical cons
tion, which varied at all commensurably with the variation i
rolling of the steel. It would seem fair, therefore, to attribute
the variation.

It may be noticed, in this connection, that we have here a
stance of rail-steel made on a formula somewhat similar to
Dudley's, the result of which was decidedly unsatisfactory.

NOTES ON THE LARGE BLASTS AT THE GLENDO LIMESTONE QUARRY.

BY FRANK FIRMSTONE, GLENDON IRON WORKS, EASTON, PA

SINCE the blast fired August 15th, 1878, which was describe
Mr. Clark,* and up to November, 1881, we have fired three sm
blasts, one in the southwest corner of the quarry, and two in the
tress of rock left standing by the first blast near the mouth o
main gangway.

We intended to keep an exact account of the stone thrown
by each blast, but the large quantity required by the furnaces
the beginning of 1879, and the time taken up by more impo
matters, have caused this to be neglected, so that it is not possi
separate exactly the cost and quantity of stone obtained during
time by the old method from that furnished by the large blasts
as the latter quantity has been much greater than the former,
notion of the value of the large-blast plan may be reached by
paring the figures from September, 1878, to November, 1881,
those for times when the old system was exclusively used.

Since 1878 wages have been raised, lowered, and again raised
to get a year of sufficiently large production for fair comparison
necessary to go back to that ending April, 1872, when wages
supplies were different from present prices and from those of 1

* Transactions, vol. vii, p. 266.

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For this reason the two most important items are given below in quantities only and not in money:

	April, 1871, to April, 1872.	Sept. 1st, 1878, to Nov. 1st, 1881.
Stone delivered to furnaces, . . .	58,051 tons.	190,180 tons.
Stone per pound of powder, . . .	$1\frac{54}{100}$ "	$4\frac{42}{100}$ "
Stone per man per day, . . .	$3\frac{68}{100}$ "	$4\frac{88}{100}$ "

The labor includes sledging all stones above about one foot cube, loading on cars, and delivering by horse-power over a railroad about a quarter of a mile long to the furnaces, and dumping there; the powder includes all that used in block holes and driving gangways, in addition to that used in the large blasts.

Steel, tools, and supplies show a considerable proportionate reduction, but the money value of this item is small in both cases.

There has been a slight reduction in the average grade of labor employed, and a corresponding reduction in average wages compared at the same rates.

In addition to the great reduction in powder and the considerable increase in product per man per day, we consider the method by large blasts as decidedly safer than the old plan. The chances of blasting accidents are greatly reduced by doing away with the sand blasting; there is no climbing along the face to drill and blast, and very little to "bar" down loose stones, and the loaders and sledgers, working generally at a greater distance from the face, are less exposed to injury from falling stones.

CONTRIBUTIONS TO THE METALLURGY OF NICKEL AND OF COPPER.

BY W. E. C. EUSTIS AND H. M. HOWE, BOSTON.

THE processes which form the subject of this paper have been experimented on in the laboratory of W. E. C. Eustis, but have not passed beyond the experimental stage. The first is the invention of Mr. J. L. Thomson, of Capelton, Quebec, Canada, the others have been invented by the writers.

THOMSON'S PROCESS FOR THE EXTRACTION OF NICKEL.

This consists essentially in first rendering the nickel magnetic, and then separating it from the materials with which it is mechanically

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mixed by means of a magnetic separator. In the case of oxidized compounds of nickel it would generally be desirable to bring the nickel to the metallic condition, in which it is most highly magnetic. The compounds of nickel with sulphur would probably, in the majority of cases, be most readily separated by bringing the nickel approximately into the state of subsulphide, in which condition it is also magnetic.

In most cases where nickel occurs with a considerable proportion of the heavy metals it would be best to effect the magnetic separation before fusing the material, since, on fusion, the nickel would enter into a chemical combination with the other metals present, as an alloy, matte, speise, or similar compound, from which, of course, the magnet could not separate it.

For cases where nickel occurs with a large proportion of iron, the following plan has been proposed by the writers: The either naturally or artificially oxidized compound of nickel is treated with a mixture of carbonic oxide and carbonic acid, or of other reducing and oxidizing gases, in such proportions that they are capable of reducing nickel so nearly to the metallic state as to render it magnetic, but still containing so much carbonic acid or other oxidizing gas as to be unable to reduce iron to that condition. It cannot be positively stated that it is possible in this way to render nickel magnetic without at the same time rendering iron magnetic, but experiments made by the writers render it probable that this can be effected. Having rendered the nickel magnetic, it can then be separated with the magnet from all matter with which it is mechanically mixed.

This method of reducing nickel with a mixture of gases not sufficiently reducing to render iron magnetic is an application of a general method patented by the writers.

Experiments tried with the nickel ores of Orford, Quebec, Canada, which contain a small portion of pure millerite, with calcite, pyroxene, and chrome garnet, gave a concentrate containing over 60 per cent. of nickel. Cobalt would probably, in most cases, follow the nickel into the concentrate.

Magnetic Process for Sulphuretted Copper Ores.

The ores of the Crown Mine, at Eustis, Quebec, Canada, contain chalcopyrite, pyrite, marcasite, and intermediate compounds, containing copper in every possible proportion from nothing to 30 per cent.;

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with these sulphuretted minerals is mixed a variable amount of silicious gangue. The writers found that, on burning these ores in heaps or in kilns, all the sulphuretted minerals became magnetic, so that, on making a magnetic separation, the whole of the copper passed into the concentrate, only a trace being found in the non-magnetic portion. Although the method is inapplicable to the Crown ores on account of the small amount of gangue which they contain, yet sulphuretted ores of copper might, in many cases, be thus treated advantageously if they contained much gangue.

The necessity of first pulverizing the burnt ore is a drawback to this as to all other methods of concentration, since the difficulty of any subsequent fusion is, of course, greatly increased by the fine state of division of the ore; it places, however, the concentrate in an excellent state for treatment in the wet way. The consumption of power in pulverizing a burnt ore is very much smaller than in pulverizing the same ore when raw, which is so much to the advantage of the magnetic separation as compared with the ordinary mechanical separation.

The following obvious extension of the above principle is proposed by the writers: Any metal existing in chemical combination with any oxide or sulphide of iron, or nickel, or cobalt, or with any other combination of either of those metals capable of being rendered magnetic, can be separated by the magnet from all gangue and other materials with which it is mixed, excepting such materials as would necessarily be rendered magnetic by the treatment which renders magnetic the metal which it sought.

The separation of gold bearing pyrites from quartz and other gangues might sometimes be advantageously effected in this way.

Electrolytic Method for Separating Nickel and Other Metals.

This process consists essentially in the precipitation of nickel and other metals from their molten slags, on bars of iron or other metal inserted in the slag. The process of Rivot and Philipps precipitates copper from its molten slags on iron bars. Our experiments prove that not only iron, but even copper precipitates nickel from its fused silicates, and, conversely, that neither nickel nor copper will precipitate iron from its slags, nor will nickel precipitate copper from cupreous slags.

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In the experiments, an oxidized salt of the metal which we sought to precipitate was fused with silicates of iron and lime, and with nitre or some other strongly oxidizing flux, to insure the complete oxidation of the metal before the attempt to precipitate it was made. After complete fusion, we inserted into the slag a bar of the metal on which it was proposed to precipitate the metal contained in the slag.

On suspending iron bars in nickel-bearing slag, they were rapidly coated with a beautiful covering of nickel, in many cases adhering tenaciously, and having a surface resembling Etruscan gold in texture. The nickel, as it precipitated, would run down the sides of the bars and trickle from their ends, forming little buttons in the bottom of the crucible. These buttons contained considerable quantities of iron, although the iron bars were suspended some distance above them. From this it is to be inferred that the iron alloyed with the freshly-precipitated or nascent nickel while the latter was running down its sides. Whether it would be possible to precipitate nickel at so low a temperature that iron would not alloy with it, we cannot state; but that nickel is precipitated from its slags at temperatures considerably below its melting-point is indicated by the following experiment: When copper bars were inserted in a melted nickel-bearing slag, the sides of the bars were rapidly coated with metallic nickel. Now at the point of contact of the slag with the copper bars, the slag can have been but slightly above the melting-point of copper, and therefore far below that of nickel. For the solid part of the copper bars cannot have been hotter than the melting-point of copper. The melted layer of copper (if any) on the surface of the solid portion must have been very thin, as otherwise it would have trickled down the sides of the solid portion, and, being very thin, its outside surface can have been but little above the surface of the solid portion, which latter could not have been hotter than the melting-point of copper; and, finally, the layer of slag which was in contact with the thin film of copper on the outside of the copper bars must have been but infinitesimally hotter than the surface of that melted copper. Nevertheless, from the comparatively cool surface of contact between the copper and the slag, nickel did rapidly precipitate.

To make this precipitation of metals from their fused slags more thorough and rapid, we propose to pass a current of electricity through the slag while it lies melted on the hearth of a

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reverberatory or other suitable furnace. The furnace-bottom would be made the anode of the current, and the metallic bars inserted into the fused slag would act as cathodes. In many furnaces the bottom contains sufficient metallic matter to make a very efficient cathode, but a carbon bottom, such as has been used for the production of ferromanganese on the open hearth, would probably act much more efficiently.

The writers hope at another time to present to you further facts as to the relative positions of the metals on the scale of electropositiveness at these high temperatures, and in slags of different compositions and different degrees of acidity.

ELECTRICAL APPARATUS AND PROCESSES FOR THE MINING AND METALLURGICAL ENGINEER.

BY N. S. KEITH, NEW YORK CITY.

No one of the live subjects of the day, to which the attention of the mining engineer and metallurgist should be turned, is of greater practical interest to him than electricity in its applications to various mechanical, chemical, and metallurgical operations. The object of this paper is to call the attention of my fellow-members and associates of the Institute to various new, as well as comparatively old, developments in the science and art of electricity which seem to promise results of advantage.

Too many of the comparatively old applications have been neglected by the mining engineer, which, if he had given them a place among his appliances, would have assisted him greatly. The telegraph may be noticed as one. Its use is, however, confined to a person having skill in the manipulations of the key, the reading of the alphabet, and familiarity with the sounder. One of the simpler forms—the call-bell—has a range of application far greater as to distance and convenience than the old wire-pull, or the hoarse voice of the windlass-man or the bucket-dumper. A few Leclanché cells, two or more electric bells, and a mile or more of wire judiciously placed will put the superintendent, at his office, in communication with the foremen of his mills and mines, so that by the aid of a code of signals, great advantages may be gained without necessitating a knowledge of the Morse alphabet, or of the mechanical voice of the sounder. The telephone furnishes a means of communication be-

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tween the often widely separated places of duty, which will save many a step, much loss of time, and wear of horse and body. It can be used by anyone who can speak.

But I wish to call attention particularly to a description of new applications of electricity which the miner and metallurgist will find, before long, so essential to his profession that their theory and practice will be taught in the schools the same as metallurgy, mineralogy, and chemistry now are. That which we may call the new electricity is due to the practical development of the theory of the conservation of energy, and the consequent production of mechanism for the generation of currents of electricity of any desired quantity and tension. So new is this electricity, in fact, that even the recent graduates of the mining schools know little or nothing of its modes of production or of its applications in practice.

I will speak of the new applications which are the result of the extensive production of machinery for generation of electricity. First comes that which appeals sensibly to the eye—light. It has been fully determined that there is no light, except daylight, as cheap as that produced by the voltaic arc; none so pure in color, none so bright. Many arc lights are in use in rolling-mills, machine-shops, hydraulic mines, surface works, and other places. The miner needs the electric light in the shaft-house, the stamp-mill, and at the furnace. If he has no engine at the shaft-house the one at the stamp-mill or furnace can be used to run an electric generator, so that not only his shaft-houses can be illuminated, but also his mill or furnace, and even the road between, much cheaper than he can produce one-tenth of the light by the use of candles or kerosene, and with much greater safety.

It is doubtful, however, whether the voltaic-arc light will be of any great practical utility in narrow veins of mines, because the light produced is too great in quantity and much more than is needed, by far, in the narrow space. Nor in the headings or stopes is it applicable, as it requires in such places too frequent moving. The work at the new railroad tunnel through Bergen Hill, at Weehawken, is successfully and economically lighted by eleven arc lights placed upon the circuit from one electric machine, two and one-half miles long. The conductors are of well-insulated copper wire, carried along the ground, upon poles, down and up the shafts, and into the various headings. The men can do more and better work in the good light. In lighting the banks at hydraulic mines, in iron-

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ore pits, in open cuts of railroad work; in fact, in all large spaces in which night-work is carried on, this light has no equal.

Take now, some of the applications of electricity which can be used by the miner and metallurgist if he has at his main engine, or water-wheel, a suitable generator of electricity. He may be sinking a shaft at the top of a mountain where it would be impracticable to place or operate a steam-engine. If he places there an electric motor, and connects it with a generator by conducting wires, he will have power at his command at the shaft, which, by the mere turning of a switch-handle, will work the whim or windlass, and hoist ore or rock, or work a pump. I have an instance at hand where electricity is now used in mining for the transmission of power, in the Loire Valley, in France, at the works of the Compagnie de la Ferronière. One Gramme machine is employed as a generator of electricity, and another as a motor attached to a drum which stands at the head of an inclined plane 110 meters long, with a grade of 4 centimeters per meter. The generator is 1200 meters from the motor. The load raised is about 800 kilograms (1760 pounds), and the ascent is made in one minute and a half. The work goes on with great regularity. The starting and stopping can be done as gently as desired. By means of a galvanometer in the circuit one can tell at any moment what is being done at the incline, whether the work is stopped, whether the wagons are coming up filled, or not, etc. The work is about two-thirds of a horse-power.

By means of this current one can ignite blasts, and work electric drills, which are said to be economical in comparison with the steam drill. The operator can stop and start the drill at will, and have all the advantages of mechanical movements without the constant, personal attention of an engineer at the shaft. He can light all his works from a central station at the mill, or other place where he has available power. Branch wires can be taken to the laboratory, where the electric current will aid him in his analyses and tests, and with it he can heat, boil, cupel, roast, and perform all the operations of the laboratory which require heat, power, or the determination of chemical affinity. It will detect imperceptible flaws in iron and steel bars, and determine the amount of carbon in steel. Think of melting metals by the fall of water! The suggestion of it even, not so many years ago, would have secured our excommunication.

It would take too long, and far exceed the proposed limits of this paper, for me to enter into the particular modes and apparatus for

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carrying on the various operations which I have enumerated; but I will briefly describe a few practical operations which can be carried out on a large scale.

For quite a number of years, in the neighborhood of Swansea, in Wales, a method of refining copper and separating such gold, silver, and other metals which the impure copper may contain, has been in practical operation on a large scale. Plates of black copper are made the anode in an electrolytic bath, consisting of a solution of sulphate of copper. Other thin plates of pure copper are made the cathode in the bath. By the electrolytic action of the current, produced by an electric generator, copper alone is dissolved from the black copper, and is deposited in a pure state upon the cathode. The impurities of the black copper sink to the bottom of the vat, and are removed from time to time and treated for their contents of gold and silver. The cathodes, as soon as they have reached the desired weight, are removed, and the copper thereon is melted and cast into ingots for the market. This process has been found more economical than any other for accomplishing the same result.

An analogous process is the one invented by me for the refining and desilverization of base bullion. The bullion, in plates, is placed in a solution of acetate of soda and sulphate of lead, and is so connected with the source of electricity as to be an anode, while plates of other metal are the cathode. Lead is dissolved and deposited electrolytically; and the deposit is practically pure. I have invented an improvement on this process, which consists in taking the skimmings of zinc, lead, and silver, which come from the kettles in the process of desilverization by means of zinc, and putting them in bags as an anode, dissolving both the lead and zinc, electrolytically, and depositing them together as an alloy, or mixture, upon the cathode plates. The contents of gold, silver, etc., are retained in the bags, and are treated for these metals by smelting. The combination of pure lead and zinc is removed from the cathode and added to the next, or some other succeeding lot of base bullion, put into the kettles for desilverization, and in that manner the process continues. In place of treating the whole mass of bullion by electrolysis, I get, in the first place, by the zinc desilverization, say, 80 per cent. of the base bullion as market lead; and, say, 22 per cent. of a mixture of rich lead and zinc, which goes to electrolytic treatment. By adding then, the pure lead and zinc to the succeeding lot of bullion, I effect the desilverization, and remove from it, as market lead, an

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amount approximately equal to the quantity of lead which is in the bullion placed in the kettle.

The process which has within a year or two been reintroduced by Siemens for melting steel by electricity can be applied to melting other metals and materials. The apparatus for this operation is comparatively simple. Take a black-lead crucible of proper size and put it in another suitably larger, and in the space between the walls of the two pack some good non-conducting material like asbestos. Introduce through a hole in the bottom of this combination a carbon rod, like one used in the electric arc light, and lute around it well with a paste of clay and graphite, so that it forms a conductor to the interior of the inner crucible. Next provide a cover, with a hole in the centre of a size to admit freely another carbon rod. Now place above the crucible the mechanism of an electric lamp so that the carbon carried by its movable rod can enter the crucible through the hole in the cover. Place in the crucible an amount of steel, or other metal, put on the cover, pass through the hole in it the carbon rod, and connect it with the movable carbon carrier of the lamp; connect the body of the lamp with the positive pole of the current generator, and then connect the carbon which passes through the bottom of the crucible with the negative pole. Immediately the upper carbon will be automatically withdrawn slightly from contact with the metal in the crucible and form a voltaic arc at that place. Fusion goes on rapidly, so that some pounds of steel can be fused in twenty minutes. The lamp mechanism serves to keep the carbon rod at its proper separation from the metal. Siemens says that there is no other equally economical mode of fusing small amounts of steel, because there is none which so concentrates the heat upon the material which it is desired to fuse. In fact the fusion takes place before the outer crucible is raised any considerable degree in temperature.

The latest development in electricity is in the so-called "storage" of it. By the term "storage of electricity," I do not desire to be understood literally, any more than I would be so understood in speaking of the store of heat in coal. It is merely a convenient term, which avoids giving a chapter in physics. The first storage of electricity, other than in its so-called static condition, was effected by Planté in his well-known secondary battery. In this case, as in all subsequent arrangements for storage, energy is absorbed in the decomposition of water by electricity, which is again given up as a current of electricity when the proper circuit is furnished;

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or, better said, when the proper association of materials is made. The value of this arrangement of Planté, and the scope of application of its modifications has not been recognized until recently.

There is nothing to be gained by expending zinc and acid for the production of electricity to effect chemical decomposition for sake of the subsequent reverse action as electric current, for the battery can be used directly whenever such current is desired. But the recent mechanical means of generating electricity have so cheapened its production that it is now sometimes desirable to store up the electricity produced, as it were, in some portable form, so that it may be utilized in a place which is not available for its direct production and use.

The line of development which has received the greatest attention is the one of which Planté's secondary battery is the type. Faure's arrangement is the most prominent. The capacity of both depends upon the porosity of the surfaces of two lead plates; one in connection with the positive, and the other with the negative pole of a source of electricity. Planté's cell acquired its limited capacity by the result of repeated oxidations and reductions, effected electrolytically, of the surfaces of the lead while in a bath of acidulated water. Faure increased this capacity by applying a coating of oxide of lead directly to the lead plates, so that the increase on a given surface, in comparison with Planté's, is in the proportion of 2000 to 75.

The operation of charging and discharging these cells is as follows: A source of electricity, having an electromotive force somewhat in excess of two volts, is connected, as before stated, with the two lead plates in a bath of water acidulated by sulphuric acid, and the current is allowed to flow in them for a time, limited by the current and capacity. The result is that the coating on one plate is peroxidized, and the other has its coating of oxide reduced to metallic lead. If the source of electricity be then disconnected, and the wires which are attached to the lead plates be kept separate, the charge will be only very slowly dissipated. But if the wires be connected, either directly or through any conducting substance, an electric current will flow in the reverse direction to that which was passed through the arrangement from the source of electricity, until the original condition of oxide on both plates is resumed. The action of the current through the plates is first to decompose the water of the solution in which the plates are immersed; the oxygen goes to the positive plate and is absorbed in peroxidation, while the hydrogen goes to the negative plate and acts there as a reducing agent, making

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metallic lead from the oxide. The reverse action takes place when the wires are connected. So it will be seen that the original electric current determined a chemical affinity, which, when circumstances allow, reasserts itself with the development of a current of electricity. On a future occasion I expect to be able to describe a storage battery of my own invention, the particulars of which I am not at present prepared to give.

Sir William Thompson found one million foot-pounds of electrical energy stored in a box weighing, with its contents, 180 pounds, made by Faure, at Paris, which he set free by use in Scotland.

The decomposition of only one pound of water by electricity absorbs about 5,300,000 foot-pounds of energy, which can be drawn at will from the storage battery through an electric motor. This equals 2⅔ horse-power for an hour. The waste of power in the process of storing is not yet well determined, but the economic results promise to be favorable, and if expectations be realized, the applications of "bottled electricity" will be many.

DISCUSSION.

PROF. C. O. THOMPSON: Can you give me any information with regard to a possible pollution of the atmosphere by the electric light through the formation of compounds of oxygen with nitrogen?

MR. KEITH: I cannot say that there are any specific data on this point. Ozone is probably formed, and that may possibly act upon nitrogen of the atmosphere to form nitric acid. Some investigators have said that nitric acid can be detected in the neighborhood of the voltaic arc, but not in deleterious quantity. Ozone acts to oxidize organic matter, and to that extent may be a purifier of the atmosphere.

MR. G. W. MAYNARD: I am glad to bear testimony to the utility of the electric light in mills. I have seen it in use in several mills having from twenty-six to sixty stamps, with great success. The apparatus used were generally those made by the Brush Company, and of the arc type. The light has a very penetrating quality, especially useful in the dust of dry stamp-mills. Under its use the amount of work done by employés is very materially increased.

Electricity is used for the refining of black copper in South Wales, by the Messrs. Elkington. I believe they use a chloride solution instead of a sulphate, so that insoluble chloride of silver is formed

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at the anodes. A very large number of tanks are used, and the electric generators are those made by Wilde, of Manchester, England. This process is also in use at Mansfield, Hamburg, and other places in Germany.

MR. H. M. HOWE: Will Mr. Keith tell us whether one pound of his apparatus, including apparatus and contents, will contain as much energy as one pound of coal; and also, roughly, what will be the cost of 1000 foot-pounds as stored in this manner, that we may see how the cost of energy so stored compares with its cost when stored in coal?

MR. KEITH: The comparative aggregates of energy are due to the combinations of two elementary substances in each case. In one to the union of oxygen and carbon for heating water in the production of steam for an engine; and in the other case to the union of oxygen and hydrogen to form water with an incidental current of electricity. The amount of energy due to these unions is well known. Twelve parts of carbon combine with thirty-two of oxygen to form forty-four of carbonic acid, with a freeing of energy equal to about 11,000 foot-pounds. Two parts of hydrogen combine with sixteen of oxygen to form eighteen of water while 6800 foot-pounds of energy are freed. Our best steam apparatus utilizes scarcely 10 per cent. of the energy due to the combustion; but it is a very poor electric motor which will not utilize more than 50 per cent. of electric energy supplied to it. Some recent machines are said to utilize from 85 to 90 per cent. Thus it will be seen that, pound for pound, the electric energy is the greater. The energy due to the union of oxygen and hydrogen to form a pound of water exceeds five million foot-pounds; and this can be stored for use electrically in apparatus weighing not two hundred pounds.

MR. HOWE: So there is more available power in one pound of your machine than in one pound of coal?

MR. KEITH: I cannot now say that when we take into consideration the weight of apparatus. But in the matter of materials which go to develop the energy; yes, and in the proportion of about fourteen to nine. And in the matter of available energy, this is probably large enough to more than counterbalance the weight of apparatus.

PROF. SILLIMAN of New Haven: I have had some experience in the deposition of copper by the dynamo-electric machine, both practically and theoretically. The process may, in my judgment, be made a commercial success. In the particular instance to which I allude

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it was not commercially successful for the want of a large enough dynamo. We had not at that time one of sufficient "quantity." One was begun by Mr. Weston, at Newark, of suitable magnitude, but failed of completion owing to destruction of his works by fire. It is merely a question of cheapness of power and the use of a suitable dynamo; always with the understanding that the attempt must not be based upon doing work beyond the capacity of the dynamo.

Steel wires are coated with copper at the works of Wallace & Sons, at Ansonia, Conn., for use in telegraphy. Copper enough is deposited on them by electricity so that small, strong conductors are produced, equal in conductivity to the much larger and heavier iron wire heretofore used.

MR. KEITH: I doubt the relative economy of the use of electricity in the separation of gold from silver. The process used in the government assay office and mints gives by-products, which pay very much of the expense of separation by means of acids.

MR. HOWE: While black copper is successfully refined electrolytically at Birmingham and Mansfield, copper refiners in this country in vain endeavor to learn how to do it. I have clients who would pay any reasonable price to the man who could carry out the electrolysis of argentiferous black copper rapidly and cheaply. This is one of the great needs of the copper industry in this country.

A very interesting process for the extraction of aluminium from its oxidized compounds has lately been described to me by its inventor. The aluminous compound is placed in a carbon crucible, which is connected as the cathode of an electric current of great intensity. A voltaic arc is then thrown across from another electrode against this carbon crucible, the current thus first melting and then decomposing the aluminous compound, metallic aluminium being deposited on the sides of the crucible.

MR. KEITH: I have heard such a process vaguely hinted at, but must say that I do not understand how aluminium can be produced except by some variation of the process.

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THE SOUTHERN SOAPSTONES, KAOLIN, AND FIRE-CLAYS, AND THEIR USES.

BY PROFESSOR P. H. MELL, JR., PH.D., AUBURN, ALABAMA.

AMONG the minerals exhibited at the Atlanta Exhibition of 1881, soapstone, kaolin, and asbestos were well represented. The first two occur in large quantities, of very pure quality, throughout the South. The last is somewhat limited in amount, yet in certain localities it exists in masses sufficiently large to pay for working; in North Carolina, Georgia, and Alabama it has been mined with some profit. I would, in this paper, call special attention to the minerals soapstone and kaolin, because their many valuable qualities seem to have been almost entirely overlooked by our Southern manufacturers. Steatite, particularly, occurs in such large quantities, and generally in such close proximity to the great iron regions of Alabama and Georgia, that it is amazing that the iron companies will persist in sending abroad under heavy expense for firebrick. It would require a much smaller sum of money to quarry this rock and place it at the various furnaces; and the results obtained, I am sure, would prove its superiority over the majority of firebrick brought into this region.

Soapstone, as well as kaolin, is found throughout the metamorphic regions of Alabama, Georgia, South Carolina, and North Carolina. Below will be found seven analyses that I have made of this mineral, taken from various points in the four States above mentioned. I have also subjected these same specimens to severe fire-tests, and the results were very satisfactory. The tests were conducted in the following manner: Small portions of the compact variety were carefully weighed and placed in a Fletcher's new crucible furnace for gas, and subjected for half an hour to a heat that will in 12 minutes fuse iron. The only effect upon these specimens was a slight change in color to a darker shade, a small loss in weight, due evidently to the evaporation of water, and, in one or two specimens, a slight degree of fusion on the sharp edges.

The first specimen subjected to investigation was taken from a large outcropping in Tallapoosa County, Alabama.

Specific gravity, 2.88; hardness, 1.9; color, blue gray.

Composition:

Water,	2.68
Silica,	65.46
Iron oxide,	2.10
Alumina,	15.02
Magnesia,	15.35
	100.61

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The second specimen came from Randolph County, Alabama, where it is found in large quantities.

Specific gravity, 2.64; hardness, 2.8; color, blue gray.

Composition:

Water,	2.00
Silica,	77.15
Iron oxide,	.25
Alumina,	1.30
Magnesia,	20.00
	100.70

The third specimen examined was taken from Clay County, Alabama, where the outcropping is bold and extensive.

I had occasion to use this rock several years since in building a furnace for treating refractory gold ores, and I used it, at the same time, to incase a large boiler that supplied the engines with steam. After long and constant use the rock, exposed directly to the fire, exhibited but little wear, and but a slight fusion on the edges.

Specific gravity, 2.89; hardness, 4; color, dark gray.

Composition:

Water,	3.57
Silica,	72.93
Iron oxide,	8.22
Alumina,	3.53
Magnesia,	16.23
	99.48

The fusion of this rock in the furnace, mentioned above, was possibly due to the presence of iron.

The fourth analysis was made from a specimen of very pure soapstone found in extensive beds near Dalton, Georgia. This property, I understand, is now owned by Mr. W. W. Lampkin, who lives in Dalton. The stone is superior in texture, and has the color and look of alabaster. It would make beautiful mantels, and hearths.

Specific gravity, 2.95; hardness, 2; color, white.

Composition:

Water,	1.60
Silica,	61.00
Iron oxide,	2.51
Alumina,	7.29
Magnesia,	27.72
	100.12

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The fifth specimen, from Northeastern Georgia, gave the following results:

Specific gravity, 2.80; hardness, 2.8; color, blue gray.

Composition:

Water,	2.84
Silica,	70.84
Iron oxide,	1.16
Alumina,	2.64
Magnesia,	22.17
	99.65

The sixth specimen came from Anderson, South Carolina. It was sent me by Professor Charles H. Franin, who informs me that the mineral exists in large quantities.

Specific gravity, 2.9; hardness, 1.8; color, blue gray.

Composition:

Water,	1.54
Silica,	57.00
Iron oxide,	5.24
Alumina,	6.42
Magnesia,	29.44
	99 64

The last specimen examined came from Swaine County, North Carolina, on the line of the Rabun Gap Railroad.

Specific gravity, 2.82; hardness, 1.8; color, blue gray.

Composition:

Water,	3.01
Silica,	65.00
Iron oxide,	.72
Alumina,	8.78
Magnesia,	27.72
	100.23

These analyses indicate the great value of soapstone for furnace linings, and the subject is, at least, worthy of the serious consideration of the iron manufacturers. From the development that is now going on in the iron regions of Alabama, there will be required in a few years a large outlay of capital to supply the necessary fire-brick to keep the furnaces intact. And yet, if the deductions drawn from the above analyses are correct, the substitution of soapstone will save a considerable amount of money, and the results, I think, will be more satisfactory.

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The Chewacla Lime Works, situated in the eastern part of Lee County, Alabama, have made a trial of this rock. The kiln has a capacity of 250 barrels a day. The company were so much encouraged that they have adopted soapstone as a lining, and it has been found equal to New Jersey firebrick. The rock is hauled some distance by wagons to the furnace.

In using soapstone for furnace purposes, care should be taken to cut the blocks so that they may be placed with the cross-section of the grain exposed to the fire. This will obviate the tendency to crumble or to flake.

The Indians made use of this mineral in many localities of Alabama, in the manufacture of various utensils. There are many excavations in Tallapoosa, Chambers, Coosa, Clay, and Lee counties in the beds of this rock, that were supposed by the inhabitants to have been made for precious metal. Not far from Tallassee Falls, there was an old Indian village called Tuckabatcha, north of which a bed of soapstone outcrops. The Indians of this village were well acquainted with this locality, and seemed to appreciate its value, because they resorted to the spot for the purpose of making culinary utensils. They had a unique way of making these vessels, which consisted in inscribing the circumference on the face of the rock, and excavating until the desired depth was reached, when they would break off the mass and finish shaping. The impressions of these vessels are seen on every portion of the excavation that they have made at this point. At the site of the old village fragments of these utensils are still to be found.

The next mineral of importance in this connection is kaolin. This substance is found in many portions of Alabama and Georgia, and its purity is all that could be desired. Near Jacksonville, Alabama, and four miles northeast of Louina, in Randolph County, of the same State, some excellent and extensive beds have been found. Specimens from the first locality gave, on analysis by Professor J. W. Mallet:

Combined silica,	89.75
Free silica,	4.85
Alumina,	88.92
Peroxide of iron,	.78
Lime, potash, etc.,	1.03
Water,	13.88
Undecomposed mineral,	.90
	99.61

This is a fine specimen of white clay, soft and easily worked.

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From the second locality, the analysis of J. W. Mallett gave:

Combined silica,	19.85
Free silica,	17.44
Alumina,	31.92
Peroxide of iron,	trace
Potash, lime, and magnesia,	.72
Water,	15.09
Undecomposed mineral,	14.28
	99.30

This is a much finer specimen than the one preceding. It is uniform in texture, and quite soft. The absence of iron from the last analysis indicates a clay excellent in quality for the manufacture of porcelain.

Some fire-clays are found in Alabama that will make excellent brick. Near Claiborne, on the Alabama River, is a finely divided silicious matter that is called by the people living there "chalk." This seems to answer well as a base for the manufacture of firebrick. It is infusible, and only requires the addition of clay to give it the proper adhesive properties to make good brick.

It is found in vast quantities, associated with buhrstone. This silicious matter passes across the State east and west, cropping out at innumerable points in bold relief. The natives use the rock quite extensively for building chimneys, and for making hearthstones, and those that have been exposed to heat for years indicate but little change.

PHOSPHORUS DETERMINATIONS IN PIG IRON AND STEEL.

BY F. E. BACHMAN, A.C., SOUTH ST. LOUIS, MO.

THERE is such a great variety of opinion concerning the best method of determining phosphorus in pig iron and steel, that a list of determinations, on a uniform sample of pig iron, together with a short description of the methods used by different chemists, and a few experiments on the accuracy of some of the methods used, may be of interest to members of the Institute.

All the results given in List A are from the same lot of drillings, thoroughly mixed, except Nos. 8 and 9, and 28 to 32 inclusive, which are from the same pig, but were taken at a later period.

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List A.

No.	Chemist.	Phosphorus found.	Method.
1	A	0.151	Molybdate and magnesia
2	A	0.154	" "
3	B	0.152	" "
4	B	0.153	" "
5	C	0.1519	" " modified
6	C	0.1523	" " "
7	D	0.152	" " "
8	E	0.154	" "
9	E	0.156	" "
10	F	0.146	" " modified
11	G	0.141	" "
12	G	0.145	" "
13	H	0.143	" " modified
14	I	0.164	" " "
15	I	0.165	" " "
16	J	0.147	" direct
17	J	0.150	" "
18	J	0.144	" "
19	J	0.154	" "
20	J	0.150	" and magnesia, modified
21	J	0.130	" direct
22	J	0.147	" "
23	K	0.151	Acetic method
24	K	0.152	" "
25	L	0.1106	Magnesia or citric acid
26	L	0.096	" "
27	L	0.100	" "
28	L	0.097	" "
29	M	0.130	" "
30	N	0.152	Molybdate and magnesia, modified
31	N	0.154	" " "
32	O	0.151	" " "
33	O	0.152	" " "
34	O	0.145	" direct
35	P	0.151	" and magnesia, modified
36	P	0.147	" " "
37	P	0.150	" " "
38	P	0.147	" " "
39	P	0.109	" " "
40	P	0.139	" direct
41	P	0.140	" "
42	P	0.152	" and magnesia modified
43	Q	0.141	" direct
44	R	0.121	" "

The brackets indicate duplicate determinations.

A. is a professor of analytical chemistry. The analyses were made by his assistant, under his direction. The assistant has had a large experience, and was formerly chemist of an iron works. He uses what I call the "molybdate and magnesia" method, as follows:

Dissolves in nitric acid, evaporates to dryness, heats in an air bath several hours at a temperature of 120° C., dissolves in hydro-

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chloric acid, filters, expels hydrochloric with nitric acid, precipitates in small bulk, made nearly neutral by ammonia, with ammonium molybdate solution [100 grams molybdic acid, 400 c.c. ammonia (0.96 sp. gr.), and 1000 c.c. nitric acid (1.2 sp. gr.)], filters, washes with ammonium nitrate [325 c.c. nitric acid (1.2 sp. gr.), 100 c.c. ammonia (0.96 sp. gr.), and 100 c.c. water], dissolves in ammonia, precipitates with magnesia-mixture [magnesium sulphate and ammonium chloride, each 1 gram, ammonia (sp. gr. 0.96) 4 c.c., water 8 c.c.], filters, washes with ammonia-alcohol (1 alcohol, 1 ammonia, and 2 water, by bulk), ignites, and weighs. Before the precipitation with magnesia-mixture silica is separated if present.

B. is a steel-works chemist, and uses the same method as A.

C. is the general superintendent of a furnace company making Bessemer iron; he was formerly the chemist. He uses the same method as A., except that after dissolving the yellow precipitate he adds hydrochloric acid to acid reaction, then ammonia till the precipitate formed redissolves, allows to stand several hours, and filters from separated silica.

D. is connected with a company making Bessemer iron. He uses from 2 to 4 grams of iron, dissolves in nitric acid, adds hydrochloric acid, evaporates to dryness, heats one hour in air bath at 120° C., and proceeds like chemist C.

E. is a Bessemer-steel-works chemist; his method is like A's.

F. is a Bessemer-furnace chemist, and works like D.

G. is a chemist of a charcoal-furnace and car-wheel-works. His method is the same as A., but he writes: "I am not surprised at my results being low, as I neglected some precautions which I should have taken."

H. is a Bessemer-steel-works chemist. He dissolves in nitric acid, evaporates to dryness and heats an hour on a sand bath, dissolves in hydrochloric acid, neutralizes with ammonia, redissolves with nitric acid and precipitates with molybdate, lets stand in a warm place four hours, filters, dissolves in dilute ammonia, precipitates with magnesia-mixture, lets stand two or three hours, filters, dissolves in hydrochloric acid (1 in 2), adds citric acid, neutralizes with strong ammonia, adding one-third the volume in excess, and lets stand four hours or more according to the amount of phosphorus present. His result (0.143), is low, and I understand from D., who has frequently checked him, that he is often as much as two-hundredths lower than himself.

I. is a Bessemer-furnace-company chemist. He dissolves 4 to

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5 grams of iron in nitric acid, evaporates to dryness in a platinum dish, ignites, "till all the nitric acid is driven off and the combined carbon burned," takes up in hydrochloric acid, evaporates low, neutralizes with ammonia, precipitates with molybdate, washes, precipitates with dilute nitric acid and molybdate, and proceeds like C., allowing for the solubility of the ammonium-magnesium phosphate in dilute ammonia. His results (0.164 and 0.165), are the highest of the lot. The similarity of the methods of H. and I., with so great difference in their results, seems to indicate either inaccuracy of method or careless manipulation, probably the former.

J. is a commercial chemist, whom I know only through correspondence. He dissolves 1 gram of iron in a half-liter flask in warm nitro-hydrochloric acid, filters, evaporates to dryness on a steam bath, separates silica by moistening with water and evaporating to dryness five or six times, takes up in nitric acid, filters, evaporates to 8 or 10 c.c., precipitates with 25 c.c. of molybdate solution, filters through weighed paper, washes free from iron with water containing 2 per cent. of nitric acid, dries till the blue stain appears, and weighs. "1.63 per cent. of this precipitate is phosphorus." Results Nos. 16, 17, 18, and 19 were obtained by this method; No. 20 by solution in nitric acid, evaporation to dryness, driving off all acid, solution in hydrochloric acid, replacing hydrochloric by nitric, then proceeding as above; No. 21 by reducing the filtrate from the silicon determination with a bisulphite, precipitating as acetates, solution in nitric acid, precipitation with molybdate, and weighing as magnesium pyrophosphate. J. says that he could not obtain good results by weighing the yellow precipitate by this method, as it generally contained a quantity of free molybdic acid. The silicon determination was made as follows: Half a gram of iron was treated with 10 c.c. of sulphuric acid (1 in 8), heated, 1 c.c. of concentrated nitric acid added, evaporated to dryness, and heated till nitric acid ceased to be given off, moistened with hydrochloric acid, dissolved in 10 c.c. of water, filtered, washed twice with water and three times with hot water containing 5 per cent. of nitric acid. This modification of Dr. T. M. Drown's method is due to Frederick H. Williams. It can be completed in one hour, and is accurate for irons not containing titanium. For phosphorus J. used 2.7927 grams, and acids in proportion, neglecting the washing with nitric acid. The method is original with this chemist. No. 22 was made by solution in nitric acid, the subsequent treatment being the same as 16 and 17. In this

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analysis phosphorus was lost through incomplete solution, iron salts being rendered insoluble in nitric acid, or by incomplete precipitation caused by silica in solution.

K. is a Bessemer-steel-works chemist. He always uses the acetic method, and says there are a great many small points, which, if not thoroughly understood, lead to low results; a fault too often apparent in determinations made by this and allied methods.

L. is a firm of commercial chemists, one member of which is a professor in a prominent technical school. They use the citric acid or magnesia method. The uniformity with which they obtain low results is remarkable. Result No. 25 (0.1106) was first reported by them, and when iron from the same pig, but a different lot of drillings, was sent them, with the express purpose of "settling definitely the question of results on phosphorus," they reported 0.096, 0.100, and 0.097. Their method is to dissolve 5 grams of iron or steel in 50 c.c. of nitric and 5 drops of hydrochloric acid, warm and concentrate till syrupy, and evaporate with 20 c.c. of hydrochloric acid, repeating the evaporation till all the nitric acid is expelled. Dilute, filter, dilute the filtrate to about 600 c.c., add ammonia till a slight permanent cloud forms, then 7 to 10 c.c. of ammonium bisulphite. Boil off the excess of sulphur dioxide, cool, add ammonia till a precipitate forms, then 40 c.c. of acetic acid, and boil twenty minutes; if the precipitate is small or slightly colored, add 5 or 6 drops of ferric chloride, filter, dissolve the precipitate in hydrochloric acid, add 2 or 3 grams of citric acid, evaporate to 30 c.c., cool, add ammonia to alkaline reaction, and precipitate with magnesia-mixture. After 16 or 18 hours filter, wash slightly with dilute ammonia, dissolve the precipitate in hydrochloric acid, add ½ to 1 gram of citric acid, reprecipitate, adding a few drops of magnesia-mixture, filter after six or eight hours, and wash with dilute ammonia (1 in 8).

M. is a commercial chemist, who works essentially as L., but uses but one gram of citric acid, and does not redissolve the magnesia precipitate. His results are also always low, so far as my experience goes, but not as low as those of L. The nearest approach to accuracy which I have seen in his work was 0.147 per cent. in an iron which contained 0.152 per cent., L. having found 0.122 per cent.

N. is a laboratory boy who thought he could do what he had seen others do. He used the method given under C., and his results, 0.152 and 0.154 per cent., show the ease with which this method can be worked, this being the boy's second determination of phosphorus.

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O. is a Bessemer-steel-works chemist. He dissolves 3 grams of iron or steel in nitric acid, evaporates to dryness, and heats on a sand-bath till the acid is driven off, dissolves in hydrochloric acid, replaces hydrochloric by nitric, filters from graphite and silica, neutralizes with ammonia, dissolves the precipitate in nitric acid, and proceeds as under C.

P. is myself. I am assistant chemist in a Bessemer-steel-works laboratory. Result No. 35 was obtained on a 10-gram sample, working as under C. Nos. 36 to 42 are experimental analyses,—36 and 37 by the same method as O., but forcing the analyses to see if reliable work could be done in one day. I could have weighed the precipitate in eleven hours safely, but had to leave it till next morning, so that it actually required twenty-three hours. In No. 38 I followed chemist I. (who reported 0.164 and 0.165 per cent.) to see if the method always gives high results. The final precipitate was washed with ammonia-alcohol, in which it is insoluble. The result, 0.147 per cent., is slightly low, as I had expected. In No. 39 I dissolved in nitric acid, and as soon as solution was complete, filtered and precipitated with molybdate, proceeding as usual. The result, 0.109 per cent., which is 27.8 per cent. low, shows that all the phosphorus is not obtained where there is not a complete separation of silica, a fact to which my attention was first called by Dr. T. M. Drown. Nos. 40 and 41 were obtained by the direct molybdate method, as follows: Dissolve 1 gram of iron in nitric acid, add 5 c.c. of hydrochloric acid, evaporate to dryness, drive off the acid on a sand-bath, take up in hydrochloric acid, replace with nitric, filter, bring filtrate to 15 c.c., precipitate with 20 c.c. of molybdate solution, filter through counter-balanced filter-papers, dry at 110° C., and weigh. 1.63 per cent. of the precipitate is, or is supposed to be, phosphorus. I had been obtaining high results by this method, and was informed that by allowing more free acid to be present and not evaporating the filtrate to 10 c.c. as I had been doing, the results would be more accurate. But this slight variation in the process carried the correction too far, and brought low results, as was the case with No. 34, worked in the same way. Eggertz's original method gives low results, but this modification of it will give almost anything you please, according to the amount of phosphorus present and the degree of concentration, and yet one can almost always get good duplicates by uniform manipulation.

Q. is a Bessemer-furnace-company chemist. He uses the same method as H.

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[illegible] IN PIG IRON AND STEE[illegible]

[illegible] chemist. He uses the direct m[illegible] [illegible] original method, or a [illegible]

[illegible] parison of results by the citric [illegible] date-magnesia method:

[illegible]

[illegible]	[illegible]	[illegible] chemist, with the per-[illegible] phosphorus by [illegible] date-magnesia method.
[illegible]	[illegible]	P, 0.155
[illegible]		[illegible]
[illegible]		[illegible]
[illegible]		[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]		P, 0.144
[illegible]	[illegible]	P, 0.144
[illegible]	[illegible]	P, 0.170
[illegible]		P, 0.173
[illegible]		P, 0.144
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	P, 0.152
[illegible]	[illegible]	P, 0.150
[illegible]		P, 0.154

[illegible], the only new letter appearing in this list, is a firm of c[illegible] mercial chemists.

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LIST C.

Mark.	Chemist, with percentage of phosphorus by the direct molybdate method.	Chemist, with the percentage of phosphorus by the molybdate-magnesia method.
Pig Iron.		
No. 1.	P, 0.161	P, 0.158
" 2.	O, 0.151	P, 0.145
" 2.	O, 0.153	. . .
" 2.	P, 0.152	. . .
" 2.	P, 0.153	. . .
" 3.	P, 0.181	P, 0.168
" 3.	P, 0.183	P, 0.169
" 4.	P, 0.157	D, 0.150
" 4.	P, 0.158	P, 0.152
" 4.	. . .	F, 0.154
" 5.	O, 0.145	O, 0.151
" 5.	P, 0.140	O, 0.152
" 5.	P, 0.139	P, 0.151
Steel.		
No. 6.	P, 0.137	P, 0.137
" 7.	P, 0.070	P, 0.068
" 8.	P, 0.076	P, 0.072
" 9.	P, 0.078	P, 0.070
" 10.	P, 0.077	P, 0.069

The foregoing results show that the direct method is far from accurate in my hands.

The next list is a comparison of results by the molybdate-magnesia method with the method proposed by N. H. Muhlenberg and T. M. Drown in a paper "On the Solution of Pig Iron and Steel for the Determination of Phosphorus," read at the Virginia meeting of the American Institute of Mining Engineers, May, 1881:*

* See page 85.

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LIST D.

No.	Molybdate-magnesia Method. Percentage of phosphorus.	Sulphuric Method. Percentage of phosphorus.
1.	0.1540	0.1560
2.	0.1340	0.1349
3.	0.1550	0.1530
4.	0.1530	0.1550
5.	0.1130	0.1139
6.	0.1510	0.1520
Average.	0.1433	0.1441

These results prove conclusively, to my mind, the accuracy of method. All the results by this sulphuric method (as I call it) obtained in one day, or from eight to ten hours, so that the met is rapid as well as accurate. I used 3 grams of iron or steel, dissolve 35 c.c. of nitric acid, evaporated with 6 to 7 c.c. of concentrated phuric acid till fumes of the latter were no longer given off, m tened with nitric acid, dissolved in water, and proceeded as us neglecting the second separation of silica. The yellow precipi separates almost instantly, and may always be filtered in less t half an hour. The magnesia precipitate separates in two hour the solution is kept below 25 c.c., and is stirred briskly for a minutes. The only drawback to this method is the unpleasant of the sulphuric acid fumes about the laboratory. Result No. in list A, is by this method.

I will now give a detailed description of a modification of the mo date-magnesia method, as used by myself. I think it reduces actual working time to as low a figure as any really accurate met Results may be obtained in eleven hours, and, in regular work results are reported in twenty-four, saving two days on the time ployed by the method of chemist A., on which this modificatio based. Dissolve 3 to 5 grams of iron or steel in nitric acid (1.2 sp. when solution is complete add 5 c.c. of hydrochloric acid, evapo to dryness, and heat on a sand-bath till all the acid is driven There is no danger of the formation of any pyrophosphate. 5 c.c. of hydrochloric acid prevents the formation of basic salts, allows faster driving without danger of spattering. Dissolve

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concentrated hydrochloric acid, using as little as possible, evaporate quite low twice with 30 c.c. of nitric acid, taking care not to render the iron oxide insoluble in nitric acid, dilute, and filter from the graphite and silica. The presence of the graphite and silica during this part of the operation renders the solution less liable to spatter when near dryness, and can in no way hurt the analysis; it also saves time which would be lost in evaporating a large amount of wash water if filtered from the hydrochloric acid solution, and, moreover, the nitric acid solution filters much more rapidly than the hydrochloric. I prefer a No. 4 beaker for this part of the operation. The filtrate and washings, which need not exceed 150 c.c., are neutralized completely with ammonia, and a slight excess added; concentrated nitric acid is then added till the solution is of a reddish yellow, then molybate solution in large excess, from 40 to 60 c.c. The beaker is heated to about 80° C. for twenty minutes, then allowed to stand at 50° C. for one to one and one-half hours, filtered, the precipitate thoroughly washed with an acid solution of ammonium nitrate [made of 325 c.c. nitric acid (1.2 sp. gr.), 100 c.c. ammonia (0.96 sp. gr.) and 100 c.c. water] dissolved in dilute ammonia, acidified with hydrochloric acid, and ammonia added till only the slightest excess is perceptible. The solution is then heated on the steam-bath till all odor of ammonia is removed, and the silica, which always separates, has become flocculent. It is filtered through a close No. 2 filter, ammonia added to the filtrate, which is then precipitated with magnesia-mixture, and stirred briskly for several minutes. The silica which separates often contains a trace of phosphorus, which may be neglected in ordinary work, but may be regained by washing the paper once or twice with hot nitric acid, precipitating with molybdate solution, heating, filtering after fifteen or twenty minutes, dissolving in ammonia, and adding this solution to main solution. If the final precipitation is to take place rapidly, the solution should not exceed 30 c.c. As soon as the solution is perfectly clear it may be filtered. In this case, as in the case of the yellow precipitate, a perfectly clear solution indicates complete precipitation, but as long as there is the slightest trace of the precipitate floating in the solution there is danger of incomplete precipitation. It is now filtered through a two-inch paper, washed with a solution of 1 part alcohol, 1 part ammonia, and 2 parts water, by bulk, transferred to the crucible without drying, and the full heat of a Bunsen-burner turned on till the paper begins to char. The burner is then turned low, the carbon burned off at a dull red heat, and the precipitate weighed as soon as cool.

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Duplicate analyses always agree within four-thousandths of one per cent., as do also the results on same sample obtained at different times. The agreement of duplicate analyses proves only uniformity of manipulation, but the agreement of results obtained weeks or months apart, I think, proves accuracy of method. I lately checked work which was done six weeks previously, and the variation from the former analyses was in one case 0.0005 per cent., and in the other 0.0019 per cent. On dissolving, filtering, and reprecipitating the magnesium pyrophosphate, identical results are always obtained. I have noted but one variation, which was a gain of one-tenth of a milligram.

The citric acid, or magnesia method, so much used, I consider inaccurate in the hands of most chemists. I could mention six chemists of prominence who use this method (five being commercial chemists), whose results are untrustworthy, and I know of but one who invariably obtains good results, though I am not quite sure that his method is the common citric-acid method. I refer to K., who calls his method the "acetic method."

There are several ways in which phosphorus is lost in this method. First, by incomplete precipitation as basic acetate; second, by the precipitate passing through the filter if it is muddy, or if the solution gets cool while filtering; third, by the solubility of ammonium-magnesium phosphate in ammonium citrate; fourth, by not allowing sufficient time for the final precipitate to separate, from twenty-four to thirty-six hours being always necessary. I remember an experiment tried in the Lafayette College laboratory in which a large amount of phosphoric acid was added to a solution of ferric chloride. The iron was first completely reduced, and then partially reoxidized by bromine, sodium acetate and acetic acid added, the solution boiled, and the precipitate filtered off. More of the iron was then oxidized and precipitated as before. This was repeated many times, till all the iron was precipitated, and yet the last portion of iron contained a trace of phosphorus. And yet we are expected to believe that all the phosphorus in any iron will collect in a precipitate containing less than two-tenths of a gram of iron!* But the chief source of error arises from the solubility of ammonium-magnesium phosphate in ammonium citrate. "From the solutions thus obtained the phosphorus is thrown down by chloride of magnesium as pure ammonio-magnesium phosphate. Since the latter is sensibly

* See Cairns's Quantitative Analysis, p. 115.

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soluble in citrate of ammonia the citric acid should be added, drop by drop, to avoid excess. . . . It is expected the results will fall out too low in the presence of much iron."*

I have never been able to obtain results by the direct molybdate method which were satisfactory, so that after working it for three months I gave it up. The difference in results on the same sample by different chemists, and the variation in the results of the same chemist on the same sample at different times often exceeds the limit of error. The tendency in my hands is toward high results when the phosphorus exceeds 0.120 per cent. These facts make me doubt the expediency of American chemists retaining this method where accuracy is required. The fact that chemists of prominence have found different amounts of phosphorus in the yellow precipitate thrown down under different circumstances, and the impossibility of always obtaining the same conditions in practice, destroys one's confidence in results obtained by this method. What are the conditions necessary to success? Can some of them be varied while others are constant? Must there be a definite amount of free nitric acid? Must the solution contain a definite amount of iron per cubic centimeter? Must there be a definite amount of phosphorus present per cubic centimeter? Must the temperature be confined between certain limits? Must there be some free hydrochloric acid present, as in the method proposed by Mr. Troilius?† I would be glad if some one who has the time and inclination to investigate these questions would tell us what are the constants and what are the variables in this method; but until we have this information we cannot feel sure of the method.

Mr. G. J. Snelus, in a paper on "The Distribution of Elements in Steel Ingots," read before the autumn (1881) meeting of the British Iron and Steel Institute, gives analyses of two samples of steel by Messrs. Burrows and Pattinson, two of England's leading chemists, in which they obtain 0.142 and 0.163 per cent. in one, and 0.052 and 0.063 per cent. respectively in the other, and says: "It will be seen that the two analysts agree in a remarkable manner, showing clearly that when the chemist's work is well done great reliance can be placed upon the actual results." These results, which are accepted as remarkably good by English chemists, would be discarded as worthless in American practice. So it is with the direct method; the results are up to the above standard, but finer

* Fresenius's Qualitative Analysis, Am. Ed., 1873, p. 622.

† See page 166.

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work is expected of American chemists. The presence of arsenic is so rare in American irons that it is hardly necessary to mention the fact that where it is present the precipitation with molybdate must be made in a cold solution. My attention was lately drawn to this element by finding 0.05 per cent. in an iron sent out by chemist L. for the purpose of comparing results by different methods. My result on this iron was reduced from 0.180 per cent. to 0.152 per cent. of phosphorus by taking the above-mentioned precaution.

To sum up, I find of three chemists working the acetic and citric acid methods in list A, two are wrong. Of four who worked the direct molybdate method three are wrong, and the fourth has a variation of 0.010 per cent. in the method as regularly worked by him. Of three working the modification of the molybdate-magnesia method, in which there is a large quantity of chlorides present with the nitric solution when phosphorus is precipitated, all are wrong, and of ten working the method so that there is only nitric acid and ammonium nitrate present with the iron solution, nine are within the limits of error.

THE GEOLOGY AND VEINS OF TOMBSTONE, ARIZONA.

BY WILLIAM P. BLAKE, F.G.S., NEW HAVEN, CONN.

THE mining district and the town of Tombstone are situated in Cochise County, Arizona Territory, at the northwest end of the Mule Pass range of mountains, in longitude 110°, and latitude about 31° 40′ N., upon the right bank of the San Pedro River, from which the town is distant 9 miles east. It is also 24 miles south of Benson station on the Southern Pacific Railroad of Arizona, and about 40 miles north of the Mexican line. Its altitude above the sea is 4600 feet. The Dragoon Mountains rise across a valley to the northeast, and the Huachuca Range similarly upon the southwest. The country is open, without timber, and the surface, where the mines are opened, is in general gently rolling, and accessible to wagons by natural roads.

The first locations were made in the year 1878 by the Scheffelin brothers and Richard Gird, the latter being well known among the pioneers of Arizona as a surveyor and miner, who contributed largely to our knowledge of the geography of the Territory in early days,

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when the dreaded Apache dominated the region. There are now, probably, over one thousand locations or claims in the district, and upwards of 2500 inhabitants.

The output of the precious metals, gold and silver, up to the first of January, 1882, aggregates $7,359,200, and over $3,000,000 have been disbursed in dividends. This product is distributed among the following-named mines and mills:

Production of Tombstone Mines and Mills.

Tombstone Mill and Mining Company,	$2,704,936 33
Contention Consolidated,	2,703,144 39
Grand Central,	1,050,875 30
Head Centre,	191,520 52
Vizina,	526,716 98
Ingersoll,	15,000 00
Sunset,	15,000 00
Corbin Mill,	40,000 00
Boston Mill,	112,007 83

Dividends.

Tombstone Mill and Mining Company,	$1,100,000
Contention Consolidated,	1,875,000
Grand Central,	600,000
Vizina,	80,000

This will suffice to show the importance of the locality for mining, and to indicate at the same time the principal claims.

GEOLOGY OF THE DISTRICT.

In going from the railway at Benson to the mines the traveller rises from the post-pliocene deposits along the San Pedro to a granitic plateau. The rock is gray and highly crystalline, and is apparently eruptive. It weathers in places into gigantic rounded blocks and masses, lying one upon another as if piled there by some Titanic force, rather than by the gentle and gradual effects of irresistible decay. This rock extends to within a mile or two of Tombstone, where stratified formations occur overlying the granite.

These stratified beds consist of quartzites, limestones, and shales, with frequent repetitions in an ascending series several thousand feet thick, but all conformable and dipping generally at a low angle from 20° to 45° to the eastward. The fossils which have been found in the middle and upper beds, consisting chiefly of *Productus* and cyathophylloid corals, show them to be *Paleozoic*, and probably

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Lower Carboniferous. The lower strata are probably older. A small shell, like *Lingula*, occurs in the shales of the Contention mine.

In addition to the stratified formations we find intrusive porphyritic dikes cutting through the strata indiscriminately, nearly at right angles, and trending approximately north and south, or a little east of north. This is the direction of the general rift or breaking of the country and of the mineral veins.

In the central portion of the district, covering the claims known as the Toughnut, Goodenough, Way-Up, Vizina, and others, erosion has exposed the outcropping edges of many strata of limestone, shales and "quartzites." Both the shale and so-called quartzite beds are of deep-sea origin, being very fine and compact in texture, with scarcely any signs of granular structure. The latter, particularly, is flint-like and very hard, and is more exactly described as a novaculite or honestone. In places it passes insensibly into limestone, apparently forming beds of silicious limestone. It is, no doubt, largely organic in its origin, and is a very fine sediment, totally different from the typical quartzites, with granular structure, found in the higher parts of the series of strata. It evidently, in forming, accumulated slowly, beyond the influence of currents, at the sea-bottom. An abundance of iron pyrites in fine crystalline grains, disseminated through the layers of this rock, gives evidence of its organic origin in part, at least. This rock has special importance from the fact that the miners in the Toughnut and Goodenough claims find it *below* the chief ore-bearing limestone. It is regularly and evenly stratified for a thickness of about 140 feet, and rests upon a thickly-bedded dolomitic limestone below. The beds above it consist of dark, black or blue limestones, and of thick beds of dark argillaceous shale, alternating with black silicious shales for nearly half a mile to the eastward. The black limestones above the novaculite are the chief repositories of the bedded masses of rich silver ore, as will be presently shown.

The whole series of beds in this central part of the district is thrown into folds, being regularly plicated in a series of wave-like flexures, the steepest and sharpest folds being on the northwest of the Toughnut and Goodenough claims facing the granitic region in that direction. These folds may be traced, but with difficulty, upon the surface, but are best seen in the crosscuts of the mines and along the drifts. In the open cut upon the Toughnut there is a good exposure of some of the beds at the crest of an anticlinal fold present-

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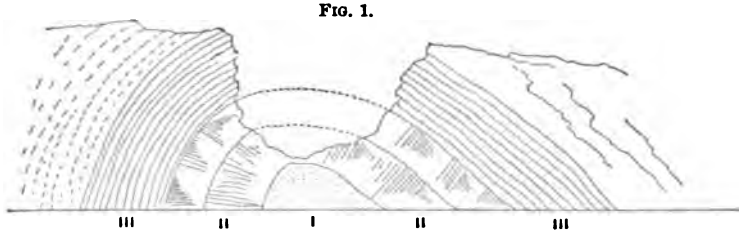
ing an appearance in section, along a northeast and southwest cut, nearly as shown in the annexed drawing:

FIG. 1.



Anticlinal fold. Toughnut.

I. Novaculite—under the limestone.
II. Limestone—bending over the novaculite.
III. Shales—bending over the limestone.

This little section is along the upper level known as the "adit." It is directly below the place on the surface where ore was found cropping out, mixed with soil and vein-stuff. At another place, upon the western end of the Goodenough, we find a series of plications, up and down, at about the angles shown, and with rich ore lying in the folds. These folds are not large, covering only a few hundred feet in extent, but are beautifully regular and well defined. As we pass up the hill, rising higher in the series of strata to the eastward, the dip becomes more regular, and coarse-grained quartzites, in thicker beds, take the place of the finer-grained deposits.

All of the formations named have not only been uplifted as described, but have been much broken and faulted either at the time of uplift or at long periods later. This is shown by the number of fissures and lines of fault, as well as by the outcrop of dikes of porphyry, and the dissimilarity of the stratified beds on either side of them, and the disjointed outcrops of the limestone beds.

THE CONTENTION MINE.

The chief fissure and ore-bearing vein of the district traverses the Grand Central and the Contention claims. These claims were located in a north and south direction upon the somewhat obscure croppings of a dike of dioritic porphyry carrying ore, in, through, and alongside of it. This location was made by Messrs. White and Parsons. The croppings were not remarkably well defined, consisting of the porphyry and a confused mixture of porphyry, chert, and quartz, with masses of porous quartzite alongside; none of these rocks rising high above the soil. There was, however, a considera-

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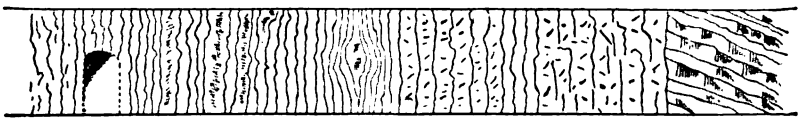
ble discoloration of the soil by iron-rust along the line, and a little digging revealed good ore near the surface. The harder parts of the dike were the most prominent, and its direction governed the direction of location of the claim. This dike varies in width from a few feet to 50 feet or 70 feet, and dips to the westward at an angle of from 55° to 65°. It cuts indiscriminately through shales, quartzites, and limestones, and is evidently of igneous origin. The contact, however, with the abutting edges of the disrupted beds is not always marked by any great change in their appearance or composition, though in places there is obscure metamorphism, impregnations of silica, and some modifications of structure. The dike itself has a distinct vertical lamination or structure through most of its substance, and is more or less penetrated by veinlets of quartz. In some portions it is highly crystalline and nearly barren, and in others consists chiefly of a feldspathic base, in which the feldspar crystals are obscure. It passes into a felsite, which, in the decomposed portions of the dike, and when slaty in structure, might be mistaken for the partly decayed shales or quartzites. Large portions of the dike are so penetrated by quartz as to consist largely of it, and might be called quartz, although close examination will show the presence of feldspar.

FIG. 2.



The accompanying cross section (Fig. 2) of the chief part of the dike taken on the first level of the Head Centre mine, upon the Contention lode, will convey a better idea than can be given in words. It shows the vertical structure, and the general distribution of quartz in vertical seams or layers, and in one place a vug, or cavity, in which there are distinct quartz crystals. In general, however, combs of quartz crystals are wanting; the quartz being in an amorphous, subvitreous state, or in the form of chert. The lamellar arrangement of this quartz near the central part of the section is shown by the little cut of full size (Fig. 3) of a fragment ground down to a plane surface. The lines represent the layers of quartz; the intermediate spaces are filled with feldspar. This lamination is typical of the vertical structure of the dike. Another fragment, with less quartz, taken at a distance of about two feet from the first,

FIG. 3.

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consists chiefly of a felsite base with obscure crystals of feldspar sparingly distributed. Examination shows it to be penetrated irregularly by veinlets of quartz, as shown by the accompanying sketches from ground and polished surfaces. (Figs. 4 and 5.)

FIG. 4.

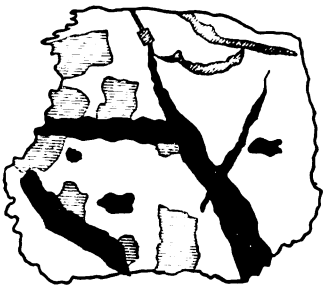
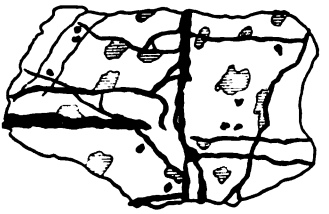


FIG. 5.



There is also a considerable amount of mineralization of the dike by iron pyrites disseminated irregularly in its substance in cubical crystals, most of which have dissolved out and left the cavities only to indicate their former presence, making in some places a spongy mass of porphyry or of quartz. Although the mine has been worked to a depth of 600 feet, and there are some 12 to 15 miles of drifts, levels, and winzes in the Contention and adjoining mines, the undecomposed ores below the water-line have not yet been reached and mined, and all the ores above are in the decomposed and oxidized condition common to surface ores. A large part of the ore is highly charged with red oxide of iron, to such an extent that the clothing of the miners becomes saturated with the rouge-like powder, and the tailings at the mills are blood-red.

There has been an extensive decomposition of the porphyry, especially along the upper 300 feet of the dike, resulting in the formation of quantities of white clay, kaolin, sometimes perfectly snow-white and pure, but generally more or less mixed with red oxide of iron. This kaolinization extends in places to the adjoining shales, and there are some white, claylike, interstratified beds which may, on further examination, be found to be altered felsitic offshoots from the dike. It is not yet possible to say what the exact nature of the ore below the water-level will be found to be. The only metallic contents so far found, with the exception of the pyrites and some galenite and lead carbonate, are gold and silver in a comparatively free state; part of the gold, if not all, being free, and the silver occurring chiefly as chloride, or horn-silver (with probably some iodide), in crusts and films, also occurring in minute crystals upon

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cleavage surfaces. The average value of silver and gold in the ores worked last year was about $70 per ton. The gold has of late increased from 20 to 25 per cent. of the value of the product, the rest being silver.

GOLD IN PORPHYRY.

One very interesting fact is the occurrence of free metallic gold, together with chloride of silver, in the midst of the porphyritic rocks, at a distance of many feet from the portions of the porphyry carrying quartz in veins, and disseminated. This gold is found chiefly in a portion of the rock apparently dioritic, containing finely-disseminated hornblende. In decomposing, this porphyry becomes steatitic, and in places appears to be changing to serpentine. The gold is found in thin sub-crystalline flakes and scales, chiefly in and along thin seams and cracks in the mass of the rock, as if it had been infiltrated and deposited from solution. This is probably the fact, and the magnesian nature of the rock has no doubt exerted an important influence in its deposition. Free gold is also found in quartz in the usual manner of association, but even in such specimens the crystalline feldspar of the dike is found.

METALLIZATION OF THE DIKE.

The time and manner of metallization of the dike may be considered as open questions, for a solution of which we must wait until the mining extends below the permanent water-level of the formation. It seems most probable that the rock, at the time of its intrusion, was pyritous, and the strata adjoining it no doubt were. It is not impossible that there may have been a concentration of the precious metals in the dike from the surrounding beds, the result of the decay and change of the pyrites diffused in the strata. On the other hand, we may suppose that the dike has been the source of the silver and gold we find in and about it.

In either case the vertical laminated or stratiform structure parallel with the walls has been an important factor in the distribution of the metals, and in the changes and modifications of the original condition of the dike. We may readily conceive of such vertical planes of structure affording planes or lines of least resistance to vertical movements, while the abutting ends of the strata, in contact with the walls of the dike, would offer great resistance by friction. The condition of the dike along a great part of its course seems to sustain and verify this hypothesis. There has evidently been considerable movement of parts of the dike upon itself, resulting in the

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formation of heavy clay seams and brecciated layers of porphyry and quartz, sometimes occupying a medial position along the dike, sometimes at one side or the other, and again along the line of contact with the country rocks. Such seams and brecciated ground are sometimes wanting, and the structure and condition of the dike remain unchanged.

The whole of the dike with the adjoining strata have been subjected to extensive movements and displacements, shown not only by breaks of continuity, but by the brecciated cross-courses and seams traversing both the igneous and stratified formations. One of these faults resulting in a throw of the northern portion of the Contention lode 150 feet to the west, and partly outside of the west side-line of the claim, has recently led to expensive litigation. The faulting seam or break has been drifted upon between the two ends of the disjointed dike. It consists of a heavy breccia of fragments of the adjoining strata, together with a strong clay wall, marking the plane of greatest movement and slip. Its direction is southwest and northeast.

In addition to the lateral movement there have been extensive vertical displacements, and it is probable that the lateral shifting may be referred to them. It would be premature to attempt an exact description of the numerous faults and mechanical changes to which the dike has been subjected. They require further study and surveys. Mr. Isaac E. James, so long and well known upon the Comstock lode as an accomplished mine engineer, is now in charge, and has the subject under investigation. We owe the first determination of the nature and position of many of the vertical faults and throws to his careful observation and surveys. Without now entering into precise descriptions of particular displacements, it will suffice to give a sketch indicative of what has occurred, producing such a confused recurrence of ore upon certain levels of the mine, as to lead at one time to the supposition that there were several dikes of porphyry and ore over a breadth of five or six hundred feet.

The movement appears to have been from the west eastward and downwards, the top of the dike being carried off in successive blocks by the sliding of masses of the stratified formations partly upon the planes of deposition of the beds (these dipping eastward and affording surfaces of easy movement), and partly upon steeper planes of fracture generally dipping eastward, as shown in the outline sketch section, which may be taken as typical.

This disruption of the dike, with its attendant fracturing and

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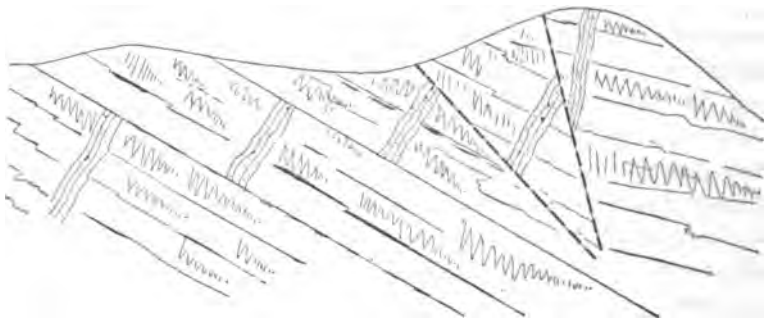
brecciation of the country rock, accompanied by the movement of the dike upon itself, and the formation of heavy clay seams, has provided favorable places for the accumulation of ore. It is generally found in the softer and most broken portions of the dike, coincident, no doubt, with the regions of greatest original metallization and subsequent movement, attended by clay seams. Such clay seams, with the accompanying ore, have by some been considered as marking

FIG. 6.



the limits of a second or subsequently-formed vein, following the dike and independent of it. This theory, formed under the inspiration of the necessity of narrowing down the vein and throwing it as far west as possible, in order to secure a greater length of it upon the Head Centre ground, would be more defensible, if in the stopes any vein structure referable to a later deposition could be found. Instead of the fragments of broken porphyry, shale, and quartz being cemented together by quartz, they are loosely aggregated, and show clearly that the formation is due to mechanical force and attrition. The clay seams are also not certain boundaries of the ore; it occurs on both sides of clay seams. The clay cannot, therefore, be taken as separating ore from waste. The seams, moreover, are not continuous, but give out, and in some parts of the dike are absent.

The only place upon the lode where water has been reached is upon the Sulphuret claim. At this point the lode intersects strata of limestone, and there is a bedded layer of ore following the stratification and connected with the dike. This ore is chiefly galena and iron pyrites. Very little has yet been taken out. So also in the Head Centre ground, at a higher level, where the dike intersects limestone, a bedded or interstratified layer of ore occurs. But the best examples of bedded deposits in the district are in the Toughnut and Goodenough claims before referred to.

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BEDDED ORE DEPOSITS.

These also are associated with dikes and vertical fissures nearly parallel with the Contention lode. One of the longest and best defined is the West-Side lode, which may be traced for about two miles, until it passes into the underlying granite. Its northern prolongation appears to cut across the Toughnut claim, and to connect with the vertical fissure and quartz croppings at the Discovery shaft on the Goodenough.

A second line of fissure cuts across the anticlinal line of the formations at the open cut on the Toughnut, and crosses the whole breadth of the Goodenough into the Way-Up claim beyond. This has been followed on ore from the open cut to the Way-Up, and is connected with the chief lateral bedded deposits. A lode has also been followed in the same general direction from the claim called the "Defence," across the Toughnut into the Goodenough. This lode is marked by very heavy croppings of quartz and flinty boulders lying above the limestone on the surface.

In the fissure extending into the Way-Up claim the ore was found in layers and bunches following the plane of the vein, extending upwards and downwards along its course in nearly vertical shoots or ore-bodies, but breaking off into the adjoining strata in flat bed-like layers, particularly where the vein intersects the lower limestone resting on the novaculite beds. These bedded offshoots from the vein are often of considerable lateral extent, following the planes of stratification on either side. We cannot yet state with confidence what the exact origin of these bedded deposits is. They may be due to the decomposition of nodular masses, but they are generally deposited in the limestone as if by replacement. They may be regarded as filling irregular cavernous spaces eroded from the strata by metalliferous solutions, and without any regular boundaries. These bedded masses do not have a symmetrical arrangement of the ore, except such as may be referred to stratification or deposition by gravity.

It is to be observed that these bedded masses of ore occupy the limestones rather than the silicious or argillaceous strata, as we might expect from the greater solubility of the limestone. Inasmuch as these limestone strata are folded and turned up in different directions, the intersection of the limestone with the vertical plane of the vein is an irregular line. At such intersections the walls of the fissure are corroded away and are obliterated, or are further apart than where the fissure cuts the silicious beds, the shales, or the quartzites.

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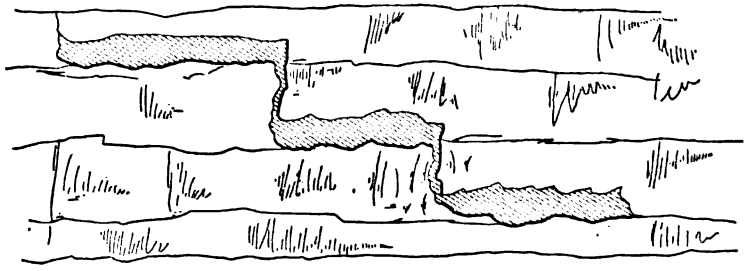
In this respect the formations are similar to many abroad. Moissenet* represents bodies or shoots of ore corresponding in their pitch to the intersection of strata with the plane of a vein. Wallace describes a series of strata in the North of England consisting of limestones and shales traversed by lodes productive in the limestone, but poor when passing through shales. Other examples might be cited.

In extent, the bedded masses of the Goodenough and Toughnut claims have been much greater than the ore-bodies of the vertical fissures, and it may be said that the greater part of the production has been from the beds or flats. They extend irregularly between the two fissures a distance of about 400 feet, measured diagonally along the dip. It is noteworthy that they follow the stratification, and then suddenly break across it vertically, following a crack or break of the bedding, and then expand again horizontally for some distance to another, dropping down by a series of steps from one layer to another in and between the limestones.

FIG. 7.



The ores found in these bedded deposits in the limestones are much more plumbiferous than the ore of the feldspathic dikes. Galenite, blende, and iron pyrites are abundant in masses, which, within the reach of oxidizing agencies, are largely converted into oxides and carbonates.

Bedded ores of this nature are also found in the limestones of the Blue Monday claim contiguous to the vertical fissure in the westward prolongation of the West-Side lode, or vertical ore-bearing fissure. This contiguity of the bedded deposits of the camp to the vertical fissures and dikes, and the occurrence of bedded ores where the dikes intersect limestone strata, lead me to the opinion that the

* Annales des Mines (6) 9, p. 10.

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metallization of the district is due to the igneous intrusions, and that these intrusions, with the accompanying impregnations and ramifying veinlets of quartz, are the true lodes, or "leads," that may be followed with confidence in the search for ores.

THE GOLD FIELDS OF THE SOUTHERN PORTION OF THE ISLAND OF SAN DOMINGO.

BY RICHARD P. ROTHWELL, NEW YORK.

In the year 1881, I visited San Domingo, in the interest of French capitalists, to examine and report upon certain "concessions" of gold-bearing gravel and quartz veins, on the Isabella and Jaina rivers and their tributaries.

This district is periodically reported to be extraordinarily rich, and there is cast around it the glamour of the mysterious shipments of gold, credited, in romance and in more or less romantic history, to Columbus and the Spaniards of the fifteenth and sixteenth centuries. Since considerable sums of money and several valuable lives have been lost in the unsuccessful search for its profitable mines, it seems desirable to place on record some of the information collected concerning the value of these famous gold fields, with the hope of facilitating the work of those who may hereafter be called on to investigate these claims, and of preventing the unnecessary waste of capital.

It is needless to add that the capitalists for whom my investigations were made abandoned the enterprise they had in view, although no doubt similar schemes will be brought forward many times in the future, as they have been in the past, under the fervent advocacy of too sanguine enthusiasts.

Since the time of the Spanish occupation of the Island of San Domingo, in 1497, when Columbus found the natives wearing ornaments of gold, more or less of the precious metal has been obtained annually by washing the gold-bearing sands of several of its streams. It is said that during the Spanish domination, when the native Indians were held in the most abject servitude, a certain amount of gold was *required* of each one as the result of his labor. Under this

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powerful stimulus, the sands of the chief gold-bearing streams were washed over, and we find, to-day, pits and other excavations along their banks, said to have been made at that time. These pits are found along the streams that to-day are known to be the richest, and it is a reasonable supposition that, under the strongest inducement which can be applied to stimulate the prospector—torture or death, in case of failure—but few really rich placers could have escaped discovery in what was then a comparatively thickly settled country; and, indeed, the comparatively large shipments of gold at that time are proof of the thoroughness with which the search was carried on. Yet with all this, while San Domingo was known at that time as a very rich gold field, its production has never been very large, and for the past few centuries, though it has never entirely ceased to produce, its output has diminished to a quite insignificant amount. Nor has this resulted from ignorance of the fact that many of the rivers of the island are gold-bearing, and that gold-bearing veins also exist; for innumerable efforts have been made to interest capitalists in their development, and an amount of information concerning the country, its placers, and quartz veins, much greater than is usually necessary to secure the development of a rich mineral district, has for many years been available. Yet to-day we find mining operations confined to the preliminary works for hydraulic mining in the northern-central part of the island, and to the explorations which were made during the early part of 1881, in the southern portion of the island, at the point which furnished most of the gold in the time of Columbus. The impression which these facts naturally produce on the practical mind is, that the placers of the island are either exhausted, as has happened in so many other countries, and the quantity of gold now existing there is too small to pay in ordinary mining operations; or that there are obstacles to success in the climate, labor, government, or some other essential element, which interfere with the working of the mines. These are the points I shall endeavor to consider in this communication.

By far the most important source of information concerning the minerals, and the value, in a mining sense, of this district of Santo Domingo, is the work of the late Dr. William M. Gabb, "On the Topography and Geology of Santo Domingo."* Dr. Gabb devoted the three

* Dr. Gabb's Report was first published in the Transactions of the American Philosophical Society, vol. xv., new series, pp. 49-259.

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years, 1869–71, to the survey of the Republic, and his report leaves little to be added upon the geology of the district. I shall merely state that my personal examination of the district fully satisfied me of the general accuracy of Dr. Gabb's geological determinations and statements. Indeed, his appreciation of the probable value of the Isabella placers, and of the vast number of quartz veins in the vicinity of the Jaina River, have been substantially confirmed by the assays and tests of the ore made for the gentlemen for whom my examination was undertaken.

I prefer, therefore, where Dr. Gabb's description and views correspond with my own, to give his own words.

According to Dr. Gabb, the main or central mountain chain is composed of a central core of eruptive rocks (syenites), which have upheaved and contorted the sedimentary strata overlying and flanking them. This core does not extend the entire length of the chain, but begins near the middle, as a great irregularly-shaped mass lying obliquely across the axis of the range. Its eastern end is abruptly cut off in the region of the Jaina. Overlying this syenitic rock, pushed up, metamorphosed, folded, and broken by it, is the great series of slates, conglomerates, and limestones belonging to the Cretaceous formation. These cover the greater part of the island, and are the oldest formation yet discovered within its limits. The sedimentary rocks, overlying the older rocks and forming the coast formation, are of Miocene and Pliocene age. The eruptions of the central range, and consequently the age of the island, Dr. Gabb says, "could not have been earlier than the period of the white chalk of Europe, and the probabilities are in favor of their occurrence during the long Eocene period. . . . . The metamorphism of the Cretaceous was completed before the deposition of the Miocene began." "Almost everywhere the metamorphosed slates carry quartz veins, sometimes barren, sometimes auriferous. These veins are usually small, rarely more than a foot or two in width, although one instance occurs on the Upper Jaina River, where a width of over twenty feet is attained. In no case have I had reason to suppose these masses of quartz to be filled fissures, in the ordinary sense of the term. In every instance, when a good outcrop occurs, so that its nature could be clearly made out, the quartz is found interbedded or interstratified with the slate, following its contortions and intimately united on the sides. In other words, they are true veins of segregation. They are most numerous in the vicinity of the injected masses of crystalline rock.

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They occur also quite abundantly in the whitish talcose rock of the main ridge. . . . . One strongly-marked feature has been observed to characterize all of the veins. Those nearest to the intrusive rocks are always gold-bearing; and those at a distance from them are invariably barren. This has been abundantly proven by innumerable examinations. No vein-mining for gold has ever been undertaken on the island, but I have caused numerous analyses to be made of specimens from various localities, always with the above results; and further, as a natural influence, every stream running through the metamorphic rocks in the immediate neighborhood of masses of syenite carries gold in its sands, while all of those running exclusively in the syenites, or at a great distance from them, are without the precious metal. Thus the Nigua and Jaina rivers are barren at their heads, but, immediately on entering the slates, they and all of their tributaries are gold-producing. . . . East of the Jaina River, that is, east of the eruptive rocks, no gold has ever been reported [in the quartz]. It is also in this formation that the little copper of the Nigua occurs."

Dr. Gabb emphasizes this opinion in many other places in his report, in speaking of the quartz veins which are everywhere abundant in the metamorphic slates. In his chapter on the geology of the region south of the main range, he says: "The district east of the Jaina furnishes but very few items of interest for the geologist. It is a plain, nearly level, or at most gently rolling, in part open grassy savannas, varied by long lines of trees bordering the water-courses, or in clumps scattered over their surface, and covering every depression. . . . The high range, east of Bassimo, which separates the waters of the Jaina from those of the Ozama and its tributaries, and which gives rise, on its eastern side, to the Isabella, is made up of clay slates, rarely talcose, and sometimes jaspery. They are much traversed by quartz veins, some, at least, of which are auriferous. A little gold has been found in the bed of the Isabella, though not enough to be of importance. In the latter river, a greenish-gray fissile claystone is the prevailing rock. . . . In the woods of Monte Pueblo, and on Madrigal Creek, this rock varies from a clay to a talcose slate, covered with a heavy red soil, the rock traversed by innumerable little quartz veins rich in gold. The whole surface of Monte Pueblo is auriferous. The greater part, if not all, of the soil would pay for washing; but unfortunately the deposit is too shallow to warrant the expensive ditching necessary to

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carry water from the Jaina to a height of perhaps forty feet above its level, opposite that point, to reach the required level. The aggregate quantity of gold is probably not sufficient to cover the expense of a ditch of two or three miles long, that would be necessary." [Lower down on the Isabella, the sands are much poorer, and the length of the necessary ditch many times as long and much more expensive.] "I have obtained from an average of a dozen to a maximum of forty 'colors' or specks of gold from a single panful of dirt over the greater part of this area." . . .

"Below the mouth of the Mano, the Jaina channel divides. . . . Here there is a little piece of flat river bottom, made up of sand and pebbles, and, in 1869, Mr. Ohle 'prospected' it thoroughly, with a view to beginning mining operations. He found gold in almost all of his pits, but did not seem to discover sufficient in any one place to warrant further proceedings."

"South of the Madrigal, on the eastern side of the river, although the hills still retain for some distance a height of two or three hundred feet above the river, the grassy surface of the savannas begins to encroach on the forest. The slates continue cropping out to the surface in a few places for four or five miles here with a recognizable high southern dip, until in the Porto Rico Savanna they are finally hidden by the gradually thickening margin of the savanna gravels, made up entirely of débris of the rocks of the Upper Jaina. Still farther south, in the savanna of Santa Rosa, these gravels, with their red sand, angular fragments of quartz, and the little streaks of black iron sand in every little rain-wash, remind a Californian irresistibly of the foot-hills of the Sierra Nevada. They are in places slightly auriferous, and, though not probable, it is yet not impossible that here, if anywhere, spots may be found where hydraulic mining might be prosecuted with success. I say not probable, because the small amount of gold in the present bed of the river seems to indicate that the quantity would be proportionately still less when spread over so wide an area. . . . West of the Jaina, below the mouth of the Mano, is a hilly region of slates, bounded on the west by the syenites, which extend across to the Upper Nigua. These hills are traversed by numerous dikes, and are full of quartz veins. The slates are an inextricable mixture of green, gray, brown, and black claystones, variously-colored jaspery slates, and some more or less talcose. Among the first I found, a couple of miles below the mouth of the Madrigal, a black rock, slightly arenaceous, very compact, and full of white

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grains. This is certainly a metamorphic shale, and yet, from its appearance in hard specimens, might be mistaken for a porphyritic rock. . . . The quartz veins are usually very small, hardly over a few inches in width, and seem to be limited also in horizontal and vertical extent. A few, however, can be measured by feet rather than inches, and Mr. Spear spent some weeks in making an experimental opening on one, of nearly three feet wide, to ascertain its character. The result of his excavation was to disclose a vertical vein, with well-defined margins intercalated in the shale. The quartz yielded a little gold by the ordinary miner's test of grinding in a mortar, and washing the powder. It is doubtful, however, whether the quantity would have been sufficient to warrant earnest mining."

"On the ridge overlooking the mouth of the Mano, at the head of two streams, called the Anones and Caballo, which unite and run into the Jaina a mile or more below the mouth of the Madrigal, is the largest quartz vein I have seen on the island. It crops out on the top of the ridge, and its down-hill side is so covered with soil and great blocks of quartz, that it is impossible to ascertain its exact width from a mere surface inspection. It is certainly from twenty to thirty feet thick, and may be much more. Fragments of the quartz are found the whole length of both streams. Gold is found in every eddy in their cañons, and I obtained it by washing even the dirt from the hill-sides. The quartz, as it appears on the surface, is more or less cavernous, the cavities lined or filled with peroxide of iron. On crushing it in a mortar and washing it, I obtained bright gold in little flakes. . . . Not only is this vein auriferous, but many of the smaller ones must contain their share of the precious metal. Over an area of several square miles of this vicinity, not only do the streams yield gold, but the earth on the hill-sides, and even on their summits, contains it. About La Horca, we found gold everywhere, and throughout the woods are innumerable pits, often twenty or thirty feet in circumference, and many feet deep, whence the Indians mined the clay and gravel, and, carrying it to the nearest stream, washed it. It is doubtful, however, if placer mining could be made profitable on a modern scale. Not but that the dirt is rich enough, but its quantity in any one place is not sufficient to warrant the construction of expensive ditches, and the slow process of carrying the earth to the water in the Indian style is too laborious and costly to be thought of. Although innumerable little streams intersect the hills, none carry sufficient water for sluices.

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Possibly some of the larger creeks, like the Caballo, Anones, Jivaná, etc., might pay moderately to wash their channels, but they would be exhausted too quickly to make them an object of attention alone. The women constantly wash gold in the creek beds, and also in those of their tributaries, using the well-known 'batea' or wooden bowl. They are content with a return of three or four reals (37½ to 50 cents) per day. I have myself obtained in the Jivaná grains worth as much as ten cents in the ordinary gold pan, and I have seen lumps weighing a quarter of an ounce, obtained by women in the same manner."

"There can be no doubt as to the sources of this gold. It is true that it is usually more or less rounded, but a very little transportation among hard stones will suffice to produce this appearance. It is never found far away from or up-stream above the quartz veins. Where quartz is most abundant, the gold is also found in the greatest quantities, and where the one [quartz] is absent, the other does not occur. On the hill-sides, the auriferous earth is clearly derived from the decomposition of the underlying slates, and finally, gold is nowhere found in those parts of the streams running only in the eruptive rocks, unless a belt of slate crosses still higher up. Nor is it ever found in the earth overlying the syenites. Throughout this region syenitic dikes are constantly encountered, and the upper half of the Jivaná runs through the parent mass, while veins of the same rock crop out in several places in the lower part of its course, as well as at the mouth of the Anones, and in the bed of the neighboring part of the Jaina. We have thus a further proof of the theory, already enunciated, that the proximity of eruptive masses is the cause of the presence of gold in the quartz veins of this country."

Dr. Gabb's explanation of the origin of the gold-bearing gravels of San Domingo is undoubtedly correct. They come from the disintegration of quartz veins. The greater part of these appear, as he says, to be merely segregated veins, intercalated in the metamorphic slates, though some of them, which occur in the syenites, appear to be true fissures, filled, probably, by segregation from the country rock, as is indeed the case with most quartz veins. The important practical question is, whether these gravels and veins contain sufficient gold to make their exploration profitable.

The work of the Indians was confined chiefly to washing the gravel found in the beds of the streams, which were far richer then than now, and far richer than that on the savannas and plains.

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On some of the streams, they also dug pits of considerable extent in the banks and small valleys which border the streams on which we now know of the existence of gold-bearing quartz veins.

The fact that these ancient works, made when the whole country was thickly inhabited, and the gold-mining industry had attained its greatest development, and was pushed with an ardor that tended much to the extinction of the native population of the island, were confined to the present river-beds, except in a small number of instances, must be taken as an indication, if not an absolute proof, that the gravel-beds, with few exceptions, did not contain paying quantities of gold, except in the concentrations of the river-beds.

A great number of tests of gravel from different parts of the plains and river-beds, supposed to be the richest, were made by two French engineers in charge of the exploration works, on which I reported in 1881. These tests were made with the pan or "batea," by native women, experts in this work, and the results obtained showed an average of less than one cent per cubic meter.

I visited a number of the more important openings made, saw the bed-rock in place at a great number of points in the plains or savannas, and tested myself, with the pan, some of the points in the river-bed which had given the highest returns. I also tested in a few places the gravel from the banks of the streams which were represented as carrying the most gold, and substantially confirmed the accuracy of those results. I found gold in many places. In none did I find any very rich pans, and it was evident that the gravel from the banks of the streams and from the plains was very much poorer than that from the beds of the rivers.

If the average amount of gold found had been *ten* times greater than it was, it would still have been insufficient to make economically possible the working of these gravels on a large modern scale by any system of mining applicable to them.

The amount of gravel in any one place is insufficient, even if it were rich enough to work, to justify the expense of bringing the water from the great distance necessary to get head or pressure, and there is no sufficient dump-room for the gravel, even if its quantity and richness were such as to justify the bringing in of the water. So that the mining value of these gravel-beds is absolutely zero. There are quartz veins, also, on the Isabella River, but though those occurring near the junction of the metamorphic rocks and the syenite are doubtless auriferous to some extent, there is nothing now known

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concerning them that would give them any commercial value, nor are the prospects of success sufficiently promising to justify the expenditure of further capital in exploration work. The assays of numerous samples gave *no* gold.

The greater part of the quartz veins of the Jaina are evidently interbedded veins in highly silicious metamorphic slates near the contact of the syenite. They vary in thickness, from a mere string of quartz, running a few feet in length, to veins of several feet in thickness, and of considerable, though unknown, length. They are, to all appearances, segregations of silica from the surrounding rocks, and are doubtless subject to the usual wide fluctuations in thickness, length, and depth, which characterize veins of this character.

There are, probably, also quartz veins in syenitic rocks which have a general north and south direction. These several veins have usually a clay parting on the walls, although, as the openings are thus far to a depth of only ten to twelve meters, where the rocks are still decomposed, it is not certain that the quartz will not "stick" to the unaltered country rock when greater depth is attained. Indeed, it is highly probable that the intercalated quartz will stick to the inclosing shales.

I had a large number of average samples, some of them over a ton in weight, taken from a number of different veins, and assayed. None of these samples showed any paying quantity of gold, and most of the ore was found to contain none at all. There is never any gold visible in this quartz, and the results of the assays should represent fairly the average value of the ore at the depths attained.

We are fully justified in concluding that while probably several of the Jaina veins contain traces or small quantities of gold, none of them carries it in any quantity which would justify the expenditure of capital even in exploration work. Engineers are frequently called upon to examine poor property, and to explode oversanguine estimates; but it is rare to find so slight a foundation as this district of San Domingo affords for the magnificent reports of incalculable riches which have been circulated periodically since the days of Columbus. The simple fact is this: its placers, which were never extensive, were long ago worked out, and thus far the most diligent search has failed to find among the hundreds of quartz veins known a single one that contains paying ore.

In addition to this, it may be stated in a general way, and without going into the detailed information which abundantly substantiates

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the opinion, that there are obstacles to success, in the form of climate, labor, government, and other essential elements, so serious as to be scarcely second in importance to the richness and quantity of the gravel or quartz in determining the investment of capital in this historic district.

THE AMOUNT OF OIL REMAINING IN PENNSYLVANIA AND NEW YORK.

BY HENRY E. WRIGLEY, C.E., PHILADELPHIA.

THE BOUNDARIES OF THE OIL REGION.

THE boundaries of the oil region in Pennsylvania and New York, as determined by the drill, embrace a much larger extent of territory than is generally supposed, being nearly 200 miles in length from north to south, with an average width of 25 miles, covering an area, within somewhat irregular lines, of about 4250 square miles.

After twenty years of development we find these lines practically the same as those laid down by McClure in his geological map of the United States, published in 1817, and denominated and colored by him as the "line of salt," which was found in quantity long before petroleum.

The eastern line of the entire oil region lies in a northeast and southwest direction, parallel to and some distance west of the Allegheny Mountains; the south line is substantially one drawn between the western boundary of Butler County and the town of Kittanning in Armstrong County; the west line passes just outside of Butler County, cutting off a small corner of Mercer, west of the towns of Franklin, Titusville, and Warren, into New York State, where it rounds off the end of this long strip in the counties of Allegheny and Cattaraugus, and joins the eastern line, near Olean, New York, north of the city of Bradford. (See map.)

The eastern line, starting from Kittanning, passes through the northeast corner of Clarion County, the southeast corner of Warren, cutting Forest County through the centre, and reaching the beforementioned extreme northeastern developments near Olean. These lines have been taken broadly to include all territory that could ever possibly come into the question as oil-producing.

These lines having been proved by the drill may be considered

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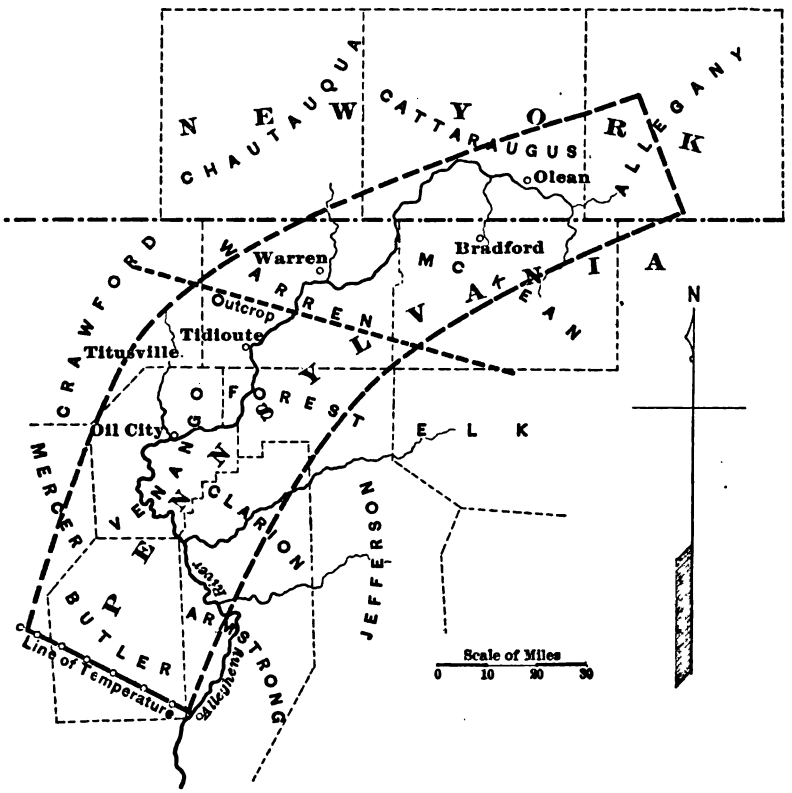
final. But there are also structural reasons for their existence. The south line is final because the oil-gathering sponge-rock on that line is found at such a depth, owing to the dip of the strata from the northwest, that the known temperature of the earth at that depth precludes the existence of hydrocarbons in any other than a gaseous form. The string of gas wells from Leechburg to South Butler County are brilliant and permanent witnesses to this fact.

The whole of this section of these States was at one time a level plain, the Allegheny Mountains being only waves of upheaval; these waves dying out as they went more and more faintly towards



the Ohio line. The vertical fissures left in the strata by these waves of upheaval allowed the gas to come up from the buried shale 20,000 feet below, and condense in the pebble rocks under a solid cap or cover of unbroken rock 1500 feet thick, where the drill tapped it in the form of oil. But where the rolls of the strata were so great

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that the fissures extended *all the way to the surface*, the gas came to the surface too, and went off in the air as fast as it was made.

The eastern limit is the line where all the fissures of the anticlinals and synclinals have come to the surface, and a very little research will satisfy one as to the certainty and finality of this line.

The reason for the west line is just the opposite; the waves all died out and there were no fissures at all, so the gas could not come up. This same reason holds good on the north line all the way round to Olean, with this exception, that on the north line the fissures do exist at a greater and greater depth as we go northward; and we can reach them by drill and torpedo if we go deep enough, provided we never exceed the safe depth for temperature of 2200 to 2500 feet. We may safely assume that at a red-hot depth under the whole country lies the vast bed of the Huron coal shales, and the question is only one of distillation and outlet; of a conduit to some natural condenser with a strong cover near enough to the surface of the earth to be above the line of temperature, so that we can tap it with the drill. No account is taken of the occurrences of oil from the upper light shales in the shallow wells at Mecca, Ottin, and elsewhere west of this western line, as they are totally unimportant factors in the general problem.

GEOLOGY OF THE OIL REGION.

Assuming the general surface of the country in Western Pennsylvania to be level, a board with its edges due north and south, east and west, tilted up slightly at the upper left-hand corner (representing the city of Erie), will give the general idea of the dip of the strata throughout this section. It will show two dips, one to the east, the other to the south; and, as the surface is level, these strata come successively to the surface as we go northward and westward. The oil sands of Butler County, for instance, if projected into the air on the line of their dip, would be 1000 feet above the level of Lake Erie; so too, the same third oil sand that we find at Tidioute, at a depth of 100 feet on the river bank, we find at 1800 feet in Butler County. The oil sands practically end and crop out all across the oil section on the line shown above Tidioute.

Now there are four conditions necessary to the production of oil in quantity:

1st. The oil shale, which exists under the entire region, and far outside of it at a red-hot depth in the earth.

2d. Such vertical fissures, caused by upheavals in these secondary

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strata, as will allow the gas generated by the heat of the earth from these carbonaceous shales, to escape upward to a point within, say 2000 feet of the surface.

3d. Between this point and within, say, 100 feet of the surface, a cooler reservoir, either of coarse pebble rock or an aggregation of small fissures to receive the gas and condense it, either with or without pressure, into oil.

4th. Over this reservoir there must be a solid cap or cover of rock to confine the products of distillation.

In the entire region south of Tidioute the third or oil sand is traced readily by the record of the wells, and the known dip of the rock of about 20 feet to the mile, the level of the wells, if on a hill, being first taken from some known point.

In the entire region north of Tidioute the reservoirs are simply crevices and have no reference to sands, but the operator carrying his experience of oil sand with him from below, drills his well down to a certain close gray sandrock as a guide. It is simply because he finds that the general horizon of the termination of the vertical fissures at the upper end occurs in this particular line of strata. The gentleness of the waves of strata at this point and the insignificance of the dip account for the general regularity of the sand-rock. But great perplexity is often caused by its occasional irregularity.

This entire long oil section of 4250 square miles may therefore be divided into two areas of pebble-rock and fissure territory respectively, with the dividing line of the outcrop of the pebble-rock a little above Tidioute. The oil region may be defined as that portion of Western Pennsylvania and New York which, within the boundaries here defined, possesses all the four requisites mentioned for the production of oil in quantity. On the east there is no cover, on the west and north it is all cover and no crevices within reach of a proper depth of temperature, and on the south the reservoirs are all below the line of temperature.*

THE PRODUCTION OF OIL.

Until January 1st, 1875, the known area of oil territory was 3115 square miles. This embraced all that part of the oil section described as pebble-rock territory lying south of Tidioute, with but trifling exceptions outside. Up to that time but 39½ square miles,

* In vol. J, of the Report of the Second Geological Survey of Pennsylvania, fuller details of these points can be found than the limits of this paper will permit.

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or about 25,000 acres, of this area had been found to be actual producing territory by the sinking of nearly 11,000 wells.

During the next three years the discovery of fresh fields became more difficult, and as the average life of a well does not exceed two and one-half years, the price of oil steadily increased. This stimulated search to such an extent that before 1879 over 15,000 more wells were put down in all directions, resulting not only in the discovery of eleven more square miles of territory but in condemning a vast portion of the outside field.

In 1879 Bradford had attained such proportions that its large product thrown on the market discouraged the expensive "wild-catting" and the deep-well sinking of the lower field; since then there have not been added more than three and a half square miles of actual producing territory, making the total amount in the pebble-rock territory 54 square miles.

From the manner of "feeling one's way," with the drill in developing the lower country, the operator, in defining every five square miles of actual producing territory, condemned 60 to 100 square miles around him by his test-wells or *antennæ*, spread out in all directions. I believe this will be accepted as a fair estimate based on experience, and will dispose of at least 800 square miles.

Now as the boundary lines of the entire oil section, ranging in length much over 400 miles, are all staked out by gas wells, dry holes, and failures, and as the area has been liberally estimated, we may safely draw around these boundaries a cordon of an average width of two miles, and that will dispose of at least 800 miles more.

There is not one particle of the territory south of Tidioute and west of the Allegheny River, as far down as Franklin, that has not either been exhausted or condemned for all purposes of quantity, by persistent and unmitigated "wild-catting." There is only left, on the west side of the Allegheny all the way down below Franklin, a small belt or strip of land, what may be called uncertain land, on the west side of Butler County and the southwest corner of Venango County, not exceeding 180 square miles.

On the east side of the Allegheny, below Oil City, there is only a small area of not more than 40 square miles in the north part of Clarion County and vicinity, which may possibly be oil-bearing. There is left on the east side of the Allegheny, north of Oil City, all that part of Forest County lying west of the great east boundary, still a wilderness, containing 350 square miles of uncertain pebble-rock territory, good for shallow wells (in spots, of from 100

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to 500 feet deep). There is left also in the interstices, so to speak, of these larger areas, and scattered over them, a number of small uninvestigated producing areas which will, no doubt, be productive later to a small amount.

Any one who will give the subject candid consideration will not claim 500 square miles of what may be called uncertain territory in the pebble-rock division of the oil section; and the amount of actual oil territory, judging by the results of twenty years in the remaining 2600 square miles, will not be more than eleven square miles.

The 1200 square miles of the oil section north of Tidioute, which has been described as crevice territory, must be considered in an entirely different manner. The key to the exact location of the boundary line of the oil section in New York, on its north and west lines, may be found in the following illustration:

The crevice which furnishes the gas in the well at Fredonia, New York, on the lake shore, was found at a depth of 1500 feet below the bottom of the oil wells near Olean, New York;* *that is why they find only gas in that section.* The crevice reservoirs lie deeper and deeper as the waves of disturbance die out northward and westward, until they pass that point of the line of temperature at which oil can exist as a fluid. This line which I have described as the final north and west boundary, can be readily tested by any one who will take the record of the wells on the lake shore and the nearest producing wells, and measure off to the point between them that calls for a mean geological horizon of 2000 feet from the mean gradient of the surface.

For the same reason no well in this section should be considered dry until it has been drilled at least 2000 feet, and well shot with torpedoes. There are no doubt a number of wells which have been abandoned under the mistaken idea of the necessity of reaching a certain sand, and which might have been driven several hundred feet to a good production.

The proportionate area of actual producing territory in the crevice oil section will approach nearly to 40 or 50 per cent. It does not follow that the actual amount of oil obtained is necessarily much greater than in the pebble-rock section, for the wells are scattered more widely apart over large areas, instead of being huddled together over a small bed of sponge-rock in the lower region. Assuming that as much as 600 out of the 1200 square miles of crevice-rock section

* See section of oil country in vol. J, 2d Geol. Survey of Penna.

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will be found to be oil territory in the manner here described, Bradford and the vicinity of Olean have already consumed 230 square miles, well determined and already on their decline. This is a matter of commercial record. The time occupied in this exhaustion is the fastest on record, only a little over two years. Some 80 more square miles of new territory are also now in full operation, around Richburg and elsewhere.

With this simple outline of the oil field, and with the records of actual results, one can readily form an estimate of the amount of oil remaining. There is no necessity for republishing here the detailed tables of statistics of production of oil. The present situation is simply this:

If 54 square miles of the lower actual territory produced in round numbers 108 millions of barrels of oil, then the eleven square miles left will give	22,000,000
If 230 square miles of crevice-rock territory produced 46 millions of barrels, then the 370 square miles remaining will give	74,000,000
Total, ...	96,000,000

It is only necessary to add that the present yearly out-put is over 25 million barrels.

Conclusion.—There are many minor questions that are necessarily excluded in a concise presentation of this subject, such as the possibility of resuscitating old oil fields; of the imperfection of the surveys of Western Pennsylvania; of the enormous waste and destruction in the early oil developments; of the origin of the oil; of the effect of the denser gravity of the surface-water on the oil in the rock, etc.

The thought which the writer desires to present plainly in this paper, which is the result of many years of close observation, is that the oil section has now reached a point of development when the amount of oil remaining can be measured with sufficient accuracy to predict definitely the life of the region. He does not wish to be considered a pessimist, he would be glad to know that he is wrong; but the possession of a check-book is not of itself an evidence of wealth. We have had a certain fixed quantity of oil placed to our credit in the Bank of Nature on which we have been drawing checks for twenty years; in 1875 we were checking out 6 millions, and in 1882 we are checking out 25 millions annually. Some day the check will come back indorsed "No deposit;" and we are approaching that day very fast.

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IRON AND STEEL CONSIDERED AS STRUCTURAL MATERIALS—A DISCUSSION.

PRESIDENT METCALF called the meeting to order, and asked Mr. Ashbel Welch, President of the American Society of Civil Engineers, to open the discussion.

REMARKS OF MR. ASHBEL WELCH.

Gentlemen of the American Institute of Mining Engineers.—As you well know an application is about to be made to Congress, by the American Society of Civil Engineers, for the appointment of a commission composed of persons skilled in the production and use of iron, steel, and other structural materials, whose duty it shall be to test the strength, elasticity, and other qualities of such materials; not simply the substances used as such, but the members of large structures composed of such materials, of the forms and sizes in which they are actually used. As I understand, the papers that will be read here to-night will have for their object to show the necessity for such tests, and therefore the necessity for the commission asked for.

As the representative of the Society of Civil Engineers, I have to thank you, gentlemen of the Mining Engineers, for the great zeal with which you have taken up this subject, and seconded the efforts of the Civil Engineers; or, perhaps I ought rather to say, initiated the efforts to get a suitable commission appointed to obtain most vitally important information which it is admitted on all hands we do not now possess.

In drawing up the memorial to Congress, in connection with some of the ablest and best informed of our Society, and in all the discussions on the subject, I have been struck with the emphasis with which the confession is made, that so little is known of the strength of the larger-sized members constantly used in building structures of the magnitude which the present requirements of the country now demand. I presume the remarks made to-night will bring this out very prominently. This is no disgrace, for with the means here-

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tofore in use it was impossible to get the information required. A good preliminary step towards the acquisition of knowledge is to feel and frankly confess our ignorance.

Paper by Charles Macdonald.

On the necessity of government aid in organizing a system of tests of materials used for structural purposes.

It may seem to be almost unnecessary to occupy the time of the Institute in further consideration of a question which has been so comprehensively treated in papers already on file in our own *Transactions* and in those of the American Society of Civil Engineers.

Unfortunately, however, the results of these concerted efforts have not been materially to increase our stock of knowledge in the direction sought for; and as the necessity for this information is becoming more and more apparent as the demand for structural materials increases, it is believed that by continuing the agitation by means of discussions in this and kindred societies, whose members are vitally interested in obtaining reliable data as to the properties of the materials they are called upon to work with, public opinion may be educated up to the importance of exerting such an influence upon the law-makers of the country as will result in the formation of a competent board, with adequate means at its disposal, to carry out this great work in a manner alike acceptable to the makers and users of the materials in question.

It may be proper in the first place to glance briefly at what has been attempted thus far, then to indicate some of the more important lines of needed investigation, and finally to consider reasons why government aid may with propriety be sought for in carrying on the work.

At a convention of the Society of Civil Engineers held at Chicago June 5th, 1872, it was, on motion of General William Sooy Smith, resolved, that,

"*Whereas*, American engineers are now mainly dependent upon formulæ for the calculation of strength of the different forms of iron and steel, not based on experiments upon American materials and manufacture; and

"*Whereas*, These differ greatly in many of their characteristics from those of foreign production, both in their nature and forms: therefore,

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"RESOLVED, That a committee of five be appointed to urge upon the United States Government the importance of a thorough and complete series of tests of American iron and steel, and the great value of formulæ to be deduced from such experiments."

Pursuant to this resolution a committee was appointed, by whose efforts Congress was induced to pass a law, March 4th, 1875, providing for the appointment of a United States Board to Test Iron and Steel, and an appropriation of seventy-five thousand dollars ($75,000) was made for that purpose.

The board appointed under the law above referred to consisted of Colonel T. T. S. Laidley, Ordnance Department, U. S. A.; Commander L. A. Beardslee, U. S. N.; Lieutenant-Colonel Q. A. Gillmore, U. S. A.; Chief Engineer David Smith, U. S. N.; William Sooy Smith, C. E.; A. L. Holley, C. E.; R. H. Thurston, A.M., C. E., *Secretary;* and they were ordered to report from time to time to the President of the United States.

It was deemed the first and most important duty of the board to provide an accurate testing machine. This proved to be a more serious matter than was at first supposed. There were no machines in the country which could be considered as giving anything more than approximate results; and to construct a new machine upon approved principles required much time and a large expenditure of money; much more, in fact, than was represented by the sum paid for it. At length a machine was completed, which for accuracy of the results obtained and range of power exerted, is unequalled, perhaps, in the world. Owing to the length of time expended in completing it, however, the original appropriation became exhausted, and the board was legislated out of existence, having had scarcely an opportunity to verify the capabilities of the very instrument which had been brought to perfection under its fostering care, and through the proper use of which so much valuable information could be obtained.

As might have been supposed, the board did not confine its efforts to the construction of this machine. About 150 specimens of steel were analyzed, and tests of their physical and mechanical properties made with a view to determine the relations between chemical constitution and useful qualities.

In wrought iron the effects of reheating and rerolling were carefully examined, and the report contains valuable information as to the different processes of making and rolling iron, the effects of various kinds of strain, the best methods of making cables for large

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vessels, and to determine how uniform strength can be secured in iron of different sizes in the bar, and how to make large masses equally strong with small pieces.

Alloys of copper-zinc and copper-tin-zinc were exhaustively examined and the results exhibited on a small triangular model from which may be obtained by inspection the characteristics of any possible combination of these metals.

Extensive preparations had also been made for ascertaining experimentally the strength of rolled beams and shape irons, for which we are now dependent almost entirely upon theoretical formulas.

Although the board had ceased to exist, the machine remained the property of the United States. It is located in the Watertown Arsenal near Boston, under the immediate charge of the Ordnance Department of the army, and is nominally at the service of engineers and others who may be able to defray the necessarily heavy expense of working it for their own private benefit. So much for what has already been accomplished. Should the efforts now being made to revive interest in the subject prove successful, the field for investigation will be found to be most fruitful of results. To mention a few instances only: In the department of bridges there were required for last year's construction not less than 80,000 tons of iron and steel, representing, say, 50 miles of bridges, over which the safety of life and limb is supposed to be assured by the accuracy of the calculations of the designer, no less than the quality of the material employed. Of this material upwards of 35 per cent. is in the form of compound sections specially adapted to resist compressive strains; and yet until quite recently all the experimental data upon which such sections are designed were obtained through the instrumentality of testing-machines which, particularly at high pressure, are liable to give erroneous results.

Quoting from Mr. Holley's paper on the United States Testing-machine at Watertown,* alluding to C. E. Emery's device for overcoming packing friction:

"It is certainly worth many times its cost in proving the worthlessness of hydraulic testing-machines as heretofore constructed. The readings of the permanent weighing apparatus as compared with those of the cylinder gauge when the piston was not revolving, showed in some cases an error of 40 per cent."

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* Transactions American Institute of Mining Engineers, vol. vii, page 259.

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It is safe to say that the recent fall of one of the most important bridges in the country would not have occurred, if, at the time of its construction, the engineer could have tested full-sized sections of his material on such a machine as the government now owns at Watertown Arsenal.

The tension members of bridges are in the form of eyebars varying in sectional area from one inch to twenty inches. Until quite recently it was assumed that the same strain per square inch might be applied indiscriminately without regard to the size of the members, or to the amount of work done upon the material in the rolls; but the few bars which have already been tested at Watertown clearly indicate that this is a most erroneous assumption; and one of the first duties of a testing board would be to establish the law governing the diminution of strength due to increased section, and to establish the relation between ductility and ultimate strength. Then would follow tests to determine proper form of head, and such other details of manufacture as might suggest themselves.

Of rolled beams there were produced last year upwards of 50,000 tons. This form of product is used chiefly in floors of buildings, often to sustain great weight, as in warehouses, and somewhat also as stringers in bridges. Their strength is estimated by theoretical formulas in which the physical constants are taken from experiments upon foreign irons tested under circumstances entirely different from what are obtained in actual practice. Fortunately for the cause of safety in the use of such materials it is probable that the formulas in question do not represent the full strength, and that a considerable amount of unnecessary weight is loaded upon our structures in consequence; but there is all the more reason why the actual strength should be determined by experiment, in order that a uniform factor of safety may apply to every member of a structure, or in other words, that it shall be equally strong in all its parts.

Did time permit, it would be possible to point out many other directions in which experimental knowledge is sadly needed, but if nothing else were done than to determine practically the laws which govern the strength of compression and tension members of bridges, and the flexure of rolled beams, a very great advance would be made in our modes of construction, and a greater safety would be assured to the hundreds of thousands of people who are constantly trusting their lives upon such structures.

What has been said regarding the importance of testing particular constructions applies equally to iron and to steel; but there are

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special reasons for investigating the properties of steel which should command attention. It is admitted to be the metal of the future, for large constructions at least; it is stronger and more homogeneous than the best iron, and owing to the substitution of mechanical appliances for wasteful muscular effort in its manufacture, there will come a time, and that before very long, when it can be furnished commercially at less cost than iron, in large quantities and of uniform quality. It only remains now to determine by a competent and disinterested authority what the general characteristics of this material are, to insure for it a continually increasing demand.

At present the finished product of the converter is principally in the form of steel rails. It so happens that the best testing-machine for a steel rail is the track, and railroad companies, by careful inspection, taken in connection with chemical analysis, are thus experimentally determining the quality of steel which answers best for that particular purpose.

For other constructions, such as bridge and ship work, very different qualities of steel are required, depending on the nature and direction of the forces to which it is subjected; and until all such questions are determined by competent and disinterested investigators, the benefits to be derived from the cheap production of steel by the pneumatic or open-hearth processes, will for a long time be confined to the favored few who are engaged in supplying the demand for steel rails.

It is hoped that enough has been said to establish the fact that a producing class of the community stands in want to-day of certain scientific information, which, if obtained promptly and in a manner to command universal acceptance, would tend to improve and enlarge one of the staple industries of the country. From the nature of the case such information can best be obtained by the assistance of the General Government. Shall the effort be made to secure such assistance?

It may be asked, why should the United States Government appropriate money for the purpose of making experimental investigations which might as well be undertaken by those who are immediately interested? In reply to this, the following quotation from the memorial recently presented to Congress by the American Society of Civil Engineers will commend itself:

"And your memorialists further represent that there is no prospect that the necessary tests will be made without the aid of government. Should private manufacturers or builders test their own

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materials they might not give the public the benefit of their experiments; such experiments would not have that assurance or impartiality and that high authority which those made under the authority of the government would have. Experiments conducted by private parties would be so different in the objects, methods, and circumstances of applying tests as to render it impossible to properly collate and verify them; they would therefore be of comparatively little value in ascertaining accurate general results."

I am aware that it is often a difficult matter for legislators to draw the line between public and private interests, and that in the multiplicity of claims made upon them they must be expected to look doubtingly upon anything that calls for money; but it would seem that where such enormous revenues are derived by the country from the effort to secure the exclusive consumption of American manufactures of iron and steel, it would be asking no more than justice for the users of these materials that the government should lend substantial aid in determining their general characteristics.

Again, the government of the United States is in possession of a most important element in the problem, the testing-machine already referred to; it represents a very considerable expenditure in money and years of patient labor, which, it is safe to say, would never have been expended had there not been a well-grounded hope that an amount of knowledge would be obtained through its instrumentality which would contribute largely to the general good.

In its present shape this machine is utterly unable to meet the wants of even such private demands as are made upon it. I am informed by an engineer now engaged in the construction of one of the most important bridges in the country, that he recently sent to Watertown nine steel eyebars to be tested, and it required seven and a half days to make the tests, while the cost to his company was at the rate of $15 for each bar. This is admitted to be due to the fact that there are no means at the disposal of the department wherewith to engage an efficient permanent staff of assistants to handle the specimens promptly, and the result is that a most valuable instrument for scientific research is allowed to remain in comparative idleness for the want of a few thousand dollars.

As to the most effectual means of expending government aid in the direction sought, there may be difference of opinion, but all are agreed as to the necessity of obtaining results which may be accepted as authority alike by manufacturers, builders, and engineers. This could be accomplished either by the appointment of a special

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committee, similar to the one created under the law of March 4th, 1875, with an adequate appropriation to purchase materials and make a comprehensive series of tests; or failing in this, a moderate sum of money might be placed at the disposal of such an institution as the one under whose auspices we are now assembled, to be expended in testing such constructions as would be furnished from time to time by engineers and others in their regular practice, with the understanding that all information thus obtained should become public property by regular publication in the *Transactions* of this and kindred societies. Could we feel assured of the permanence of a special commission, the members of which could devote the necessary time to the work, this would doubtless be the most satisfactory to a large majority of those interested.

There are uncertainties, however, connected with all such special legislation in a government constituted as ours is, that should be carefully considered in this connection lest we should be compelled to undergo a similar experience to that which befell the previous board, which, from no fault of its own, was brought to an untimely end after having perfected the means by which, for the first time, really accurate testing could be done in this country.

It is to be hoped that eventually a Department of Public Works will be instituted, having co-ordinate power with other departments, as of the Interior, for example, to which all questions relating to the expenditure of public money, either for internal improvements or for scientific investigations connected therewith, may be referred, and through which the interests of the producing classes, including engineers, builders, and manufacturers, may receive that special consideration which their importance demands.

Whatever method may be adopted will be liable to defects as a matter of course. We must be content to go slowly and surely, to be patient and judicious in advocating our claims, and above all to bear in mind that if our cause is a good one, as we believe it to be, and we do not succeed in impressing its importance upon Congress, it will, in all probability, be our own fault.

Remarks of General Meigs.

I do not know that I can do any more than to express my entire concurrence in the views which have been already expressed by Mr. Macdonald. It appears to me that he has gone over the whole subject. I might add in regard to appealing to the Govern-

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ment for an appropriation, that the Government itself is the largest single user of these materials; the railroads together use more, but there is no single organization which uses so much. Congress appropriates the money with which are erected the large government structures that are found now in almost every city. It is stated in the public press that it is contemplating the erection of a hundred new government buildings in a hundred cities this year. In all these buildings the floors are supported upon rolled iron beams, and the principal materials used for roofs are iron. These buildings are all dependent for their cost upon the size of their dominant members, and, as a consequence, upon the factor of safety which the engineer allows; so that as long as there is uncertainty as to the proper coefficient of safety, perhaps from two to five times as much metal as is actually necessary may be put into these members. There are other materials used in buildings,—brick, stone, marble, timber,—but these materials we buy by the cubic yard or cubic foot, they are comparatively inexpensive; metal we buy by the pound, and at this time we pay pretty high prices for the pound; so that if we can reduce our general coefficient of safety, we save perhaps one-half to two-thirds of the actual cost of the material used. Congress sits under a roof of iron, its building is crowned by an iron dome; it is about building a new navy and is considering whether it shall be of steel or of iron, and the result will depend upon the comparative qualities of steel and iron. I see it stated by a gentleman, eminent in the actual practice of steel making, that his company is prepared now to furnish steel which shall be guaranteed a tensile strength of 60,000 pounds to the square inch, with 30 per cent. elongation. One can hardly imagine a more admirable metal.

Therefore I think that this society can with a good heart go to Congress, and if they can only convince some of its leading members of the necessity of more knowledge on this subject, it appears to me they must meet with success.

Remarks of Captain Lyle.

I was very much interested in Mr. Macdonald's paper, and I can say that there is nothing in it to which I cannot heartily subscribe. In speaking of the want of knowledge that has existed, and still exists, among engineers in regard to structural materials, their strength, etc., my own experience has taught me to doubt the reliability of the ordinary testing machines.

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In one case I tested a piece of metal for gun-barrels, using very small specimens, which gave a tensile strength of over 65,000 pounds to the square inch, and yet the barrel burst at a much lower pressure. In another case a barrel burst in service-firing with a pressure of from 25,000 to 27,000 pounds per square inch, as indicated by the Rodman pressure-gauge. I took a piece that was blown out, turned down the specimen, tested it, and it gave 88,794 pounds tensile strength; yet the barrel had burst when subjected to not over 27,000 pounds pressure to the square inch. These results made me hesitate about accepting *any* results from a testing machine of that size. Further experience in testing metals have tended to convince me of the inaccuracy of small testing-machines.

As to the machine at Watertown Arsenal, I know that there is such a machine, that is, I have seen it. I believe the original board (U. S. Board to Test Iron and Steel) published some of the results obtained with that machine. They got out a report, and of that report I know not how many copies were printed, nor how many were received by the engineers of this country. I could not get one, though I tried for some time. I have no doubt that you will find that the men who were most interested never received them.

I had the curiosity to go, to-day, to the Ordnance Office in order to learn what the machine was doing. I have now in my hand an official copy of a letter written by the commanding officer of Watertown Arsenal to the Chief of Ordnance, in answer to certain inquiries as to the capacity of the testing-machine at that point. I did not see the letter of inquiry, but understand that this letter gives short and categorical replies to the questions asked by the Chief of Ordnance.

The letter reads as follows:

WATERTOWN ARSENAL, February 13th, 1882.

THE CHIEF OF ORDNANCE.

SIR: I have the honor to reply to your interrogatories of the 10th inst., as follows:

1st. The greatest number of tests made in a day of 8½ hours is seventy (70). The least number is one-half of a test.

2d. The cost charged to private parties for tests is determined by the time taken to make them.

3d. The machine is in constant use when Mr. Howard is not otherwise engaged in making out reports of tests made for private parties.

4th. The cost of running the machine is $18.00 per day.

Respectfully, your obedient servant,

[Signed] T. T. S. LAIDLEY,
Colonel of Ordnance Commanding.

Under the present arrangement, from lack of funds and sufficient

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force to operate the machine, it is manifest that the Watertown instrument cannot be depended upon to furnish the data of which it is capable. It does not supply the information needed by the engineers of the country at large.

The act of Congress, approved February 24th, 1881, appropriated $10,000 for "preserving, using, and operating the United States testing-machine at the Watertown Arsenal; *provided*, that the tests of iron and steel, and other materials for industrial purposes, shall be continued during the next fiscal year, and report thereof shall be made to Congress." The fiscal year referred to ends June 30th, 1882. The reports made must be submitted to Congress at its next session, before they can be printed. The red tape involved in the process of getting the reports printed causes great delay in their appearance. The only way to have them promptly is to issue bulletins from time to time; these bulletins to contain merely abstracts of the work done and the results obtained.

Special care should be taken to record all *failures* in experimental tests, as it is the failures rather than the successes that are most instructive.

It seems to me that the location of the machine is singularly unfortunate, being in an out of the way place, inaccessible except by local trains, and so far from the great centres of iron and steel manufacture. Governor's Island, New York harbor, has been suggested, but that is open to objection on the ground of inaccessibility. Frankford Arsenal, Philadelphia, has also been mentioned, but that is rather far from the great central railroad depots. My own preference would be for New York city as a location, but that would involve a considerable expenditure of money for the purchase or rent of a suitable building, and the introduction of power for its manipulation. Again, the risk of injury by fire is much greater in a city than at some one of the arsenals. The risk and difficulty of transportation should not be overlooked.

But wherever the machine may be located, an active young man should be placed in direct charge for the sole purpose of operating it under the direction of a competent board. The idea of individual ownership of the instrument should be discouraged, and the person in charge should appreciate the fact that the machine is designed for the benefit of the government and the engineering interests of the entire country.

It is my opinion that a commission or board of specialists should be created to project and carry out tests with the machine. The

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board should not be too large, else diversity of opinion will paralyze its efforts. The board should be subdivided into committees, whose members are experts or specialists in their own lines. There would be great necessity for this subdivision of the work. The board should be attached to one of the executive departments of the government, no matter which one, so as to have a recognized head, in order to leave its members untrammelled by the clerical labor incident to disbursements and accounts.

I think army officers are ready and willing to work in unison with manufacturers and engineers for the success of this great work. It has always been my own desire and practice to give the best information in my possession on any point to those who desired it, no matter whether civilian or soldier, American or foreigner. Although there may be a few obstructers in the army, as elsewhere, I think I am justified in saying that the army is willing to aid in this work. I feel assured that the Chief of Ordnance will lend all the assistance in his power, consistent with his duty as the head of a great executive bureau of the government.

Remarks of Mr. E. D. Leavitt, Jr.

I DESIRE to state briefly my views respecting the great practical value of the Watertown testing-machine, and the necessity that exists for an able permanent commission to supervise its operations, in order that the results of all tests made thereon may be properly worked out and rendered available for public use.

It is doubtless known to the Institute that this machine has, for the past two years, been placed at the service of the public upon payment of a per diem charge. It was my privilege to be among the first to use the testing-machine, and the results of my first experiments were of such importance, owing to the great capacity and extreme accuracy of the machine, that it has since become my practice to have tests of all materials used in constructions that came under my charge, made at Watertown.

As a consequence, nearly one hundred tests have been made on my account directly, and some two hundred and forty additional for work built from my designs. It may be confidently affirmed, that the factor of anxiety on all these structures is exceedingly small as far as the quality of material is concerned, and it is undoubtedly a very great advantage for parties interested in construction to have

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any tests that come within its scope made on the Watertown machine. The engineering professions, and through them the general public, do not reap the advantages that they ought, when it is considered that the machine is public property.

It may be asked, why do not those who have made use of the machine make public the results of the tests that have come under their notice? To this the reply must be, that the interests of clients are generally paramount to the interests of science, leaving no time for properly working up the data for publication. It is also natural that special information bought and paid for, should be considered personal property. Engineers are almost invariably very busy men, and rarely, very rarely, is there found one among us, who, like our lamented Holley, has apparently time and capacity for all things.

My advantages have been exceptional, from the fact that my residence is but a short distance from the Watertown Arsenal, thus affording the opportunity of being personally present during tests, with very little loss of time. Such privileges can be enjoyed by very few of the profession without serious inconvenience. The machine is operated in a first-class manner by those at present in charge, but with the rapidly-increasing demand for tests, a larger force of experts is absolutely necessary, all of whom should be of such reputation as to command the confidence of the profession and the public.

There seem to be certain men who, like Regnault and Tyndall, are born experimenters; and such men are needed for the permanent commission, in order that the full advantages of the great testing-machine be realized.

Our knowledge regarding the strength and behavior of materials under strain is yet very limited. The best and most experienced constructors admit and lament this. In these days of high speed by railways and steamships, of long-span bridges, and deep mines, engineers must know what materials will safely endure; life depends upon it, and every means available for increasing and disseminating information on a subject which is of such vital consequence to all should be provided.

I freely acknowledge that I have learned more about structural materials through the tests made at Watertown during the last two years, than in twenty-five years' previous experience. At the same time, I am aware that I have by no means secured all the advantages

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to be obtained from the data in my possession, or that might readily be secured by a commission of experts specially devoted to the duty, with ample time for observation, and provided with the best-known appliances for making experiments.

Remarks of Mr. T. C. Clarke.

The history of iron construction in this country well illustrates the three phases of thought described by Auguste Comte, the French philosopher.

The first is the era of faith, when belief in the safety of structures rests on the authority of the designer. The second is the era of criticism, when plans of structures are analyzed with much mathematical skill, but the data upon which the chain of reasoning depends is assumed upon insufficient experiment. The third, upon which we are now entering, is a scientific era, which demands experimental proof. It also demands that this proof shall be derived from experiments made on full-sized specimens, such as are in actual use, and not upon toy models.

Until the construction of the United States testing-machine, now at Watertown Arsenal, it was impossible to make such experiments with accuracy. We now have a machine in which we can test full-sized specimens of every part of a bridge or other structure that we want to use, and under the same conditions in which it is actually used. The next thing is to get money to make these experiments available. No private individuals can afford to do it, and even if they could, they might wish to keep the results to themselves. So that the next point is that we want money, and that, I believe, everybody thinks we should ask Congress for. We want also, as has been said, some one who shall make a business of testing, and who has plenty of time. Persons who are employed in private business are too much in a hurry; they want to do a thing and get done with it, and then do something else; but government officers are entirely free from this feeling; time to them is of no account, and in experimenting that is the very element that is of value; it does not do to be hurried; the great thing is to get it right and to test your results, and go over it, again and again. And the experimenter who operates the machine must be some person educated up to the use of it. We then want a general advisory board who will indicate a plan of experiments, collect the results, and publish them. Some experiments were made the other day at the Watertown Arsenal upon full-sized

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Phœnix columns. Any one can see at once that these are very valuable experiments, because we have certain columns all of the same quality of metal, the same workmanship, and the same cross-sections, and differing only in length. As far as these columns are concerned this would be all, but it would then suggest itself that we make experiments with the same columns alike in other respects but with different cross-sections, and then test them made of steel, and so on. The engineer is often asked, why don't you use steel? We can't expect to know anything about it at all until experiments are made in the way that I have indicated in some such machine as this. I venture to say that Messrs. Fowler & Baker, who expect to build the great bridge over the Firth of Forth, in Scotland, cannot find out anything about the strength of the parts of their structure, unless they have a machine equal to our government machine. Then, the last thing of all, after having made the experiments, they ought to be published monthly and sold in all book-stores. Then every engineer could get a report, and would have questions to ask and suggestions to make, and would at once write to the board and give them the benefit of his thoughts. These suggestions would be one of the most valuable results of prompt publication.

Remarks of Mr. O. Chanute.

In discussion of Mr. Macdonald's paper, I can say little more than to add to the general acknowledgments of ignorance, and like several of the gentlemen who have preceded me, make one of those confessions which are thought to be good for the soul.

Having had some experience in the erection of bridges during past years, I am aware that we yet need much information in order to proportion them to the best advantage.

I would more especially like to emphasize three of the points mentioned by Mr. Macdonald, as among those upon which we lack knowledge; these are: first, the behavior of steel; second, the proportions of compression members; and, third, the influence of the size of a bar upon its strength per square inch.

First, as to steel. While we all acknowledge this as the material of the future, our position may be said to be still one of expectancy. Few engineers are bold enough to employ it largely in bridges, and those who do, find such serious difficulties in obtaining uniform grades of it, are so puzzled by apparent anomalies and unexpected phenomena, that it requires considerable faith and courage to apply it in large structural masses. A series of systematic experiments,

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such as have been partially made by various European nations in their government shipyards and elsewhere, by which we should be enabled to connect the influence of the chemistry of steel and of the process of its manufacture, with results of the various modes of working the product into its final shape, would doubtless add so largely to our knowledge of modern structural steel, as to make reasonably clear much that we now only suspect, and give us the necessary knowledge and confidence to avail ourselves of the increased strength and economy which this metal promises. At present we know that the strength exists, but we also know that steel is brittle under many conditions; and where human lives are at stake, where failure would involve such disastrous consequences, we dare not avail ourselves of the strength of that metal, unless reasonably sure that it will not break.

Second, as to compression members of structures. They are now proportioned upon formulas which were framed many years ago in England, and which were based upon very few experiments, some thirty in number, if I recollect rightly. Not only were those experiments tried upon pieces materially smaller, and of different shape from those which we now generally use, but they were made with English irons, which are found to differ in some respects from the characteristics of American irons. We have accordingly made some changes in the constant numerical factors of the formulas, to attempt to adapt them to our use, but we now find from the experiments recently made at Watertown with the government machine, for Messrs. Clarke, Reeves & Co., that even the modified formulas are erroneous, and do not agree with the actual condition of affairs. In fact there is great uncertainty as to the actual strength of the bridges which we are daily erecting. Their strength is of course limited by that of the weakest part, but while we endeavor to make every part equally strong, as well as we know how, yet we are almost entirely ignorant as to what is actually the weakest part of a bridge of any magnitude, and of just where it would give way first, if loaded to rupture.

While no man knows exactly what weight will crush flat say a 4-inch cube of wrought iron; we do know that it begins to yield, without recovering its shape, at pressures of some 36,000 to 40,000 pounds to the square inch. Accordingly with the aid of the formulas I have mentioned, we proportion compression members for an assumed crippling-point varying from say 35,000 pounds to the square inch for pieces of ten diameters in length, down to about

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24,000 pounds to the square inch for pieces forty diameters in length, and upon these we allow strains varying from 7000 to 4800 pounds to the square inch, as working compressive loads; while in tension we allow some 10,000 pounds to the inch on iron, with a breaking strength of 46,000 to 50,000 pounds, and an elastic limit of 26,000 pounds to the square inch.

Now in my judgment, the crippling-point of a compression piece corresponds more nearly with the elastic limit in tension, than with the ultimate or breaking strength. The probabilities of any compression bridge member being strained up to the crippling-point, are nearly as remote as the probabilities of a tension member being strained up to its elastic limit, and to have all parts equally strong, should experiments justify this view, we should base our assumed margin of strength (you will note that I do not use the term "factor of safety," as I think it misleading), upon the *crippling* strength and the *elastic limit* of the material. As for myself, I believe that we are now making our compression members considerably stronger than the tension members; that if we were to break down a bridge by fair loading, granting of course that all the *connections* should be made stronger than the body of the pieces they attach together, rupture would probably first take place in one of the tension members. But then while so believing, I do not *know*. I confess my ignorance upon this point, and until this ignorance is removed, I shall go on specifying for proportioning bridges in the old way, and with the old formulas.

Third. Not only is there great uncertainty concerning the actual strength of compression members, but we do not know accurately the strength in tension of full-sized bars worked to various dimensions, and with a different amount of pulling and squeezing in the rolls.

In the bridge specification of the New York, Lake Erie, and Western Railroad, we require that full-sized pieces of flat, round, or square iron, not over 4½ inches in sectional area, shall have an ultimate strength of 50,000 pounds per square inch, and stretch 12½ per cent. in their whole length, while for bars of a larger sectional area than 4½ inches, we allow a reduction of 1000 pounds per square inch, for each additional square inch of section, down to a minimum of 46,000 pounds per square inch. This was adopted after consultation with various manufacturers of iron, who had large experience; but the discrepancies between the data which they furnished, and the views which they expressed when the printer's proofs of the spe-

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cifications were submitted to them, showed clearly that they did not agree as to results, and that they too were in need of further experiments upon full-sized members of various dimensions.

In the government machine at Watertown, we have for the first time in this country, a machine adequate to obtain correct results upon full-sized members. It has a capacity of 400 tons, while former machines at various bridge works had a capacity of only 150 tons, and could not be trusted to work accurately to even 100 tons. Tension members, being composed of several parallel bars, could be tested in detail, provided the dimensions of the bars did not exceed say 8 inches by 1 inch, but compression members, with a sectional area of say 12 to 20 square inches, could not be tested at all, and resort had to be had to small models, which, as already stated, are not found to give the same results as full-sized pieces.

Tests are made for two purposes; first, to ascertain the best *form* in which the metal can be placed to resist the strains; and, second, to ascertain the *quality* of the metal itself. Upon the latter point experiments are being made every day by manufacturers, bridge builders, and corporations which are erecting structures. Every time we contract for a bridge we test many specimens of the materials which go into it, and the corporation with which I am connected, has tried hundreds of experiments upon the quality of the metals it has used, which will be very much at the service of a testing board, should one be appointed. These experiments have been carried as far as we had any interest, that is to say, to the point of ascertaining the quality of the metal furnished; but we have preserved many of the specimens, and a testing board could ascertain the chemical constitution of each, and, perhaps, be enabled to connect the various behavior of the specimens with their chemical characteristics and the process of their manufacture.

For information as to the best *forms*, however, we must rely upon the government machine, and especially upon government aid, as no single firm or corporation has sufficient interest at stake to warrant it in planning and paying for the great cost of a systematic series of experiments, to ascertain what are absolutely the best shapes into which to put the members (chiefly those of compression), by testing full-sized pieces. Moreover, if any firm or corporation were to become possessed of information which is so much needed, it would probably endeavor to give it commercial value, and to recoup its expenses, to say the least, by keeping such information for itself as

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long as it could, and the general public of metal-users would remain in its present ignorance.

It seems to me, therefore, that the General Government is the proper party to institute and carry out the needed experiments, not so much because, as has been claimed, the materials to be tested are "American" iron, steel, and other metals, but because there is need of general information, which no single other party is likely to obtain and make public. The government has the machine, it has abundant resources, and the manufacturers and engineers of the country, with universal good-will, stand ready to tender their aid and technical knowledge.

Now one word as to the organization of the inquiry and the doing of the work. There should be some general plan of operations, and this would probably be best evolved by the deliberations of a commission, but the actual work will be chiefly done, as I think, by one man. That is to say by the man who may be placed in general charge of the experiments, and whose duty it will be (to draw an analogy from industrial organizations) to act as chief executive officer, or superintendent if you will, and to plan and draw deductions from the various needed experiments. The commission, if commission there be, may lay out the general plan, but it must have some one head in charge of the actual carrying of it out.

But how shall we secure the selection of the very best man to put into that position? He may be appointed in many ways. He may be selected by the President of the United States, or by the Secretary of War, or by the Secretary of the Navy, or by the head of one of the government bureaus, or by the commission which has been suggested, and which would thus act (to refer again to industrial organizations) as a board of directors or trustees. It does not in my judgment make much difference how he is selected, provided we get the right man. A mistake may be made at first, and changes may have to be made, until the right man, a man like Kirkaldy, in England, is brought forward, who shall possess the necessary technical skill, the executive ability, and the high standard of accuracy and thoroughness to conduct the experiments, as well as the talent to deduce general conclusions from them.

Upon the whole, I believe that the best way of selecting such a man, would be through a board of commissioners. This plan has been found to work best for joint-stock companies carrying on large operations, and I hope that Congress will organize the work through

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a commission as prayed for in the memorial of the Society of Civil Engineers.

Paper by Mr. Alfred P. Boller.

on the need of a national board for testing the metals of construction.

In the victories of peace as well as of war, the science of engineering has played a prominent, if, indeed, not the leading part. While it might be interesting, and food for profitable thought, to trace the development of engineering from early times in its bearings upon the social betterment of mankind, it will be sufficient on the present occasion to suggest a few thoughts that it is hoped will aid the unprofessional listener to an appreciative consideration of the subject-matter laid down for to-day's discussion, and possibly lead the professional brother to a higher conception of the profession to which he belongs.

Since the advent of the railway era, it is difficult to grasp the sequence of historic events that have led to the wondrous development of mechanical science, making possible the civilization that is our daily boast, and opening up a vista of future intellectual and moral advancement among the nations of the earth, before which the imagination becomes hopelessly lost. Even now, looking back over a period of only half a century, we often fail to realize the vast change in the relations of individuals and nations to each other, brought about by the results of those mechanical discoveries which, having made the whole world kin, exercise a resistless levelling influence that bears fruit politically in the spread of republican ideas, and morally in the elevation of the individual through the facilities given to the dissemination of Christian ideas and general intelligence. In this view, it seems almost like a work of supererogation for a body of representative men of one department of that science to which the whole world owes so much, to meet here at the centre of our national life to plead not only for a practical recognition of the national importance of the work to which their lives are devoted, but also for national aid, on a scale beyond that of private effort, to the end that mechanical science may be carried to a higher plane than ever yet attained, each step on the way being of material benefit to every man, woman, and child in the community. Possibly this is strong language, but none too strong when we consider that the work for which we plead is one affecting not only vast scientific and commercial interests, but also human life, to a degree little ap-

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preciated by those whose occupation or calling is outside of pursuits in the domain of applied science.

What so intimately affects the people in every household is worthy of the profoundest sympathy of the legislative powers, and the members of any Congress who grasp this subject as its magnitude and importance demands, will live to see not only a great work performed in the interests of science and manufactures, but also a web of protection thrown around every hearthstone in the land, by removing to a great extent the ignorance and empiricism to which too many broken bridges, fallen buildings, and imperfect machines testify.

It is popularly supposed that engineering is an exact science, treading, as far as it is developed, on positive data. If this were true there would be no need for a government commission for testing the metals of construction. While engineering theory has been most thoroughly established, covering almost, if not entirely, all departments of the science, engineering facts are in an unsatisfactory state, and must remain so until experiments on the strength of materials are made on a scale which a national government alone can undertake. During the last decade we have discovered the fact that our knowledge of the properties of iron and steel is less accurate than it was heretofore supposed, and that the physical data, in use all over the world, are based on crude experiments made on a scale utterly insufficient to determine the true value and application of the metals in the forms and masses as applied in the arts. To the layman, with all the triumphs of modern engineering before him, this statement may seem contradicted by those engineering successes; but such works are always based upon a "factor of safety," made large enough by prudent engineers to cover up not only the imperfections of workmanship always inseparable from the best of human endeavor, but also those deficiencies of exact knowledge regarding the properties of metals used in construction. Every factor of safety, therefore, is composed of two parts, the factor of safety proper and the factor of ignorance. It is the determining of the exact proportions of this factor engineering science now demands, that ignorance may be eliminated, and dishonesty prevented from taking refuge in the protection due to the margin allowed for the factor of ignorance. This factor of safety, such as it is, is the sole protection of the millions of people daily carried by the railways of the world and all the other modes of mechanical transportation, to say nothing of the occupants of innumerable public buildings and places of assemblage. Further, as an economical measure, the establishment of a factor of safety based on exact data deserves more than a passing

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comment—an economy resulting from a direct saving in the use of materials in the broadest sense, and in the prevention of their abuse.

Measured by product, the United States is rapidly coming to the van among the nations of the world in the manufacture of iron and steel, being second only to Great Britain. The past year witnessed some 6,000,000 tons of iron and steel made in this country, the scientific use and economical application of which becomes of the first national importance. It may be a revelation to some, that there is no standard of authority as to the strength of the metals of construction, and that engineers are by no means agreed upon the limits of strain that may be imposed on iron and steel under given conditions. Some years ago they thought they knew more than they do now, but under more exacting requirements, more extended observation, and higher technical training, they have arrived (with rare exceptions) unanimously to the conclusion that no authoritative data exists for designing metallic structures, nor can exist until some central authority, like a national government, establishes a system of experimenting upon the metals on scientific principles, and on a scale that bears some proportion to the shapes and masses actually used in construction.

From the preceding remarks it must not be concluded that engineers have all these years been practising a rule of thumb, and depending upon their intuitive perceptions for the successful practice of their profession. It must be remembered that metallic constructions are of comparatively recent date, and that their development is dependent upon a great volume of experimental data that takes more or less time to accumulate and analyze. Much experimenting has been done, and is now being performed continuously in all parts of the world by private individuals, either for trade purposes or private investigations. A considerable portion of such work gets before the profession in a fragmentary sort of way, finally getting into our textbooks as authority, supplementing the English tables that have been handed down through all the engineering textbooks that have ever been published. And in this connection it is proper to confess that American practice is largely governed by the tradition of English experiments, which have come before the world in a more accessible shape and greater fulness than could be elsewhere obtained. These English experiments, dating from the construction of the Britannia and Conway bridge-tubes, have ever since been published the world over as authority, and the names of Eaton, Hodgkinson, and Sir William Fairbairn, by whom those experiments were devised and conducted, will ever live as pioneers in the art of

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iron construction, and be revered as long as the profession of engineering has a follower,—particularly that of Fairbairn, whose whole long and busy life was devoted to experimental knowledge, and whose researches, to this day, are largely our guide in practice. The next step toward a still more accurate knowledge of the constructive value of iron and steel was taken, when the experiments of Kirkaldy were made, about 1862, under the patronage of one of Scotland's great ship-building firms, that of the Messrs. Napier & Sons, by whose permission they were given to the world, adding largely to existing knowledge. These experiments disclosed many important factors in the behavior of metals under stress, overlooked by all previous experimenters, and opened up a field of investigation that has ever since been profitably worked. But these, as well as all preceding ones, were conducted on what we may call specimen sizes of the various irons and steels manufactured in Great Britain, and, while valuable as far as they go, they are utterly insufficient as standards by which to judge the absolute value of structures as a whole, or of the parts of which they are composed, to say nothing of the fact that American interest is in American metals and not in British.

Chemical composition, as affecting the strength of iron or steel, has only recently claimed attention (growing primarily out of the Bessemer steel industry), and cannot be neglected hereafter. It is a matter of comparatively recent record, that iron or steel in small bars has a very different value from the same metal rolled in large sizes, and that the shape in which such bars may be rolled very materially modifies their strength. In general we have discovered that while experimental specimen sizes, on which our tables are mainly based, give *comparative* values for different qualities of iron or steel, they are misleading as to *absolute* values, only determinable by testing the sizes and shapes as used in actual construction. The question of abrasion has still to be investigated, and when one reflects that this is a vital question in the economical use of steel rails, the importance of such an investigation cannot be overrated. In steel, particularly, there is much to learn, at least by the profession at large; few engineers have the temerity to use it with the present lack of knowledge of its physical properties; yet it is a metal that the constructive demands of the age are forcing on the attention of engineers, and, as the metal of the future, a full and elaborate series of physical and chemical experiments upon such shapes and sizes as are needed in actual construction should be undertaken at the earliest moment.

Another line of investigation is greatly needed, and that is the

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effect of vibration and impact, on which the life of metal structures largely depends. Some few investigations in this branch of experimental research have been made by Fairbairn in England, and in considerable number by the late Baron von Weber in Germany, both pointing in a general way to a period of destruction under repeated impact and vibration, when such successive impacts strain the material beyond a certain point. It would make a long catalogue if we were to enumerate with any fulness the unexplored regions awaiting the investigator into the properties of the metals, and would involve a degree of technical statement out of place in this paper.

Enough has probably been said to awaken an intelligent interest in the thoughtful lay mind, and it is hoped it will bear fruit in season. The American Institute of Mining Engineers is only an advance guard in pressing the attention of this subject upon Congress. The two other representative bodies of engineering science, the American Society of Civil Engineers and the American Society of Mechanical Engineers, are thoroughly in earnest in the matter, and will soon be heard from, blending, as it were, with the voices of all minor societies and mercantile associations, the factories, mills, and workshops of the country, in one harmonious demand that Congress shall consider the grand scheme presented to it for action; a scheme in the interest of no faction or body of men, but in the interest of the whole people.

This idea of establishing a National Board for the testing of American metals is not a new one, and it is proper in this place to refer to past efforts in that direction. In 1875 such a board was constituted by act of Congress, on recommendation of the House Appropriation Committee, of which the lamented Garfield was chairman. The members of the board were selected with great judgment, and represented satisfactorily the various departments of the industrial and engineering branches of science. The Ordnance Department of the army had previously been at work in this direction for ordnance information, and had already in hand the construction of a testing-machine on a new principle, and of such proportions that experiments could be made on a scale, and with a degree of accuracy, never before attempted. On the creation of the Testing Board the work of the Ordnance Department was consolidated with it, and everything promised fair for results that would not only be of inestimable value to our own people, but be of great national credit.

The board lost no time in organizing, and laid out an exhaustive scheme of work, covering all possible uses of the metals, under sub-

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committees for each special department of investigation. They at once took in hand the testing-machine, previously contracted for by the Ordnance Department, and used every effort for its early completion. This was prolonged far beyond the anticipated time, and swallowed up in its cost almost the whole of the original appropriation of Congress, viz.: $75,000,—a sum far in excess of the original estimate, thus materially crippling the work of the board at the very outset.

The testing-machine selected by the Ordnance Board, and approved by the National Board, is the product of years of labor and expenditure on the part of Mr. Albert H. Emery, civil engineer. It was the first one ever built on the magnitude contemplated, and involved such novel principles, leading to an accuracy hitherto unapproached by any other machine ever built or conceived of, that last year the Massachusetts Charitable Mechanic Association, on the recommendation of a committee of Fellows of the American Academy of Arts and Sciences, conferred its "Grand Medal" on the exhibit of the results of the testing-machine as the "single exhibit most conducive to human welfare." This machine is one of the world's mechanical wonders. It will exert a pressure so delicate as to weigh to a nicety the strength of a hair or an egg-shell, and so powerful as to bring into play a force of 400 tons, and in either case with absolute accuracy. This machine being a novelty in itself, like all new contrivances, could not be confined to any initial cost, and had to be carried through from beginning to end, as every original effort must be, regardless of ultimate cost. In the meantime, during the building of the machine, the members of the board did a great deal of independent work, largely preliminary, and often at their own expense. As before remarked, the unexpected disbursements required for the testing-machine hampered the board from the start; for while a great range of experiments was possible independent of the testing-machine, such as the breaking of full-sized girders and trusses, they all required an expenditure in a large way. Still, much valuable work was done, far more than is generally supposed, which has been admirably covered in a paper by Professor R. H. Thurston, read before the American Association for the Advancement of Science at its Nashville meeting in the summer of 1877. This paper sketches the organization of the committees, with the work laid out for each, and the recapitulation in this place of the division of labor and the scope of the investigations, will bear witness to the wisdom of the committee, and serve to emphasize the previous remarks upon the importance of a National Testing Board for the industries of America. These committees were:

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country, asked for an appropriation of $50,000 to continue their work. In July the Senate added an amendment to the bill for sundry civil expenses of the government, appropriating $70,000 for the use of the board to test iron and steel. This was opposed by the House members of the Conference Committee, and the amendment was stricken out, and about the only satisfaction that could be obtained for the opposition of the House was in the remark of its chairman to a prominent engineer desiring light on the subject: "Can you tell me how many Democrats there are on that board?" The anxious inquirer left, a sadder and wiser man; probably wondering if iron and steel had undiscovered political characteristics, as well as chemical and physical. A compromise amendment, however, was finally agreed upon, covering an appropriation of $19,396.98, and at the same time legislating the board out of existence June 30th, 1879. The work continued with the above financial support, and is a matter of record in the committee's reports, a summary of which may be found in Professor Thurston's review of the work of the board, before noted. Strong efforts were successively made, not only to secure the repeal of the law discontinuing the board, but to continue the appropriations. These efforts were not only cordially met by the President, but made by him the subject of a special message to Congress. Prominent members of Congress made personal efforts to maintain the board as a national institution, and every possible argument was used for favorable congressional action. All these efforts, however, failed, and the board was compelled to accept the inevitable, and calmly resign itself to annihilation as its ultimate and speedy fate. In the year preceding the board's dissolution, the House, by resolution, called for a report of its work, no report up to that time having been presented. This report was subsequently presented to the House and ordered printed. In the debate upon the work of the board, the speaker, and former chairman of the Appropriation Committee, to whom allusion has been made, showed decided opposition to the board and its work, and presumably on the same ground. Finally, in June, 1878, the whole matter was settled by the passage of a law practically remanding the testing-machine to the custody of the Ordnance Department, making it accessible for the service of private parties, under a system of fees to cover the expense of operation and maintenance.

This is, in brief, a history of the rise, decline, and fall of the United States Board appointed to Test Iron and Steel. It belongs to the past, and we must commence anew, referring only to so much of

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the past as will serve to enlighten the future. What is wanted now, is a more comprehensive law for the proposed new board than the one creating the old, and one fully recognizing the national character of the work. To this end the powers of the board should be fully defined, and all necessary provision made for its successful operation. Such a board should not be tacked on in any way to an army department, but should be an independent body, reporting to the Secretary of the Treasury or the Secretary of the Interior. The work is almost entirely civil work, just as much as that of the Coast Survey, and should remain in existence as long as there is a metallic question, so to speak, remaining unanswered. Now that the testing-machine is an accomplished fact, the board could profitably spend $50,000 per annum in experimenting, and the centre of its operations should be in the city of Washington, to which point the testing-machine should be removed from Watertown Arsenal, its present abiding-place.

The operations of the board should be reported in yearly volumes readily obtainable by the scientific men and metal workers of the country, either by sale for the mere cost of publication, or by a proper system of distribution, whereby the object of its publication would be accomplished. There is a tradition that an edition was published of the only report made to Congress by the old board. But the report has failed to reach the very class of men who could profit by it, leading to a vague suspicion that its distribution was based on political and not scientific methods. If it is not possible, under the existing methods of distributing public documents, to give the board absolute charge of distributing the yearly reports of its own work, then the manner of distribution should be defined by the law creating the board. Too much attention cannot be paid to this branch of the board's work, since the very object of its creation would be defeated if the results of its work were not easily accessible to all seeking information they contain.

We are now brought to the consideration of rather a delicate question, about which there are differing views, and that is, the remuneration, if any, of the men engaged on the work of the board. This work, if properly attended to, would be an exceedingly engrossing one, calling for the practical abandonment, for the time being, of any other pursuit, and it would seem manifestly unfair to demand that such labor and sacrifice should be unrecompensed. Again, the great majority of men qualified for such work (and there are not many such available) would be deterred from accepting service on the board, from

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sheer financial inability to perform unrecompensed labor. Whatever is worth doing is worth doing well, and to expect qualified men to do without recompense the work called for by such a board,—a work that will so richly compensate the American people,—is to believe in a degree of self-sacrifice that should not be looked for this side of Utopia, and should not be asked for. The only objection possible to urge against a paid board, all or in part, is the one usually attaching to government salaried positions, and the possibility, therefore, of unworthy or incompetent appointments. In other words, the board might get into politics, and the question of the chairman of the House Appropriation Committee, before related, would be asked with redoubled earnestness.

Be this as it may, it should be thoroughly understood that the moment the proposed board takes on a political bias its usefulness is ended. Nor can such a board lend itself to the glorification of any individual or set of men. Its aim is purely a scientific one for practical ends, and as such must be established on its merits alone; and if this view is not prominently kept in the foreground, and made the basis of all legislation concerning it, the whole matter had better be dropped. The work of such a board is not a matter of one year or two years; it may take ten years to cover the field as it should be covered, but whether it takes a longer or shorter time, it should be constituted on such a broad basis as to be free from haste in the examination of the various schemes of experimenting it must necessarily undertake. We must not be impatient for results, but bear in mind that the questions asked by the modern engineer are exceedingly complex ones, and that while he would have been content a few years back to know the amount of strain an iron bar, for instance, would stand before rupture, he demands now to know the reasons that cause different bars to give different results, or the same bar to give different results under varying treatment, or why a small bar behaves differently from a large bar of the same material. And, further, in regard to steel, all that is known is so little compared with what is yet to be learned about its properties and adaptations, that the field of research is almost appalling in its magnitude and intricacy. To all these questions the yearly reports of the board would give answers which would have the weight of undisputed authority.

When the work of such a board is completed it would be a grand culmination of its work for the United States Government officially to promulgate, as an American standard, the limits under which American metals should be used, particularly in those works to the

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stability and endurance of which human life is intrusted; and while perhaps it would be straining a point to add legal criminality to a violation of such standards, the moral sense of the community would very soon attach such criminality, and bold would be the man, no matter how unscrupulous, to use metals excepting under the conditions officially prescribed. Science would have sway in the factories and workshops, and the days of the vendors of mantraps would be numbered; ignorance, if not eliminated, would be kept under wholesome restraint, and the field of that useful but dangerous member of society,—the "practical man,"—would be much restricted.

The theme of the proposed "Board for Testing American Metals of Construction" is indeed an inspiring one, the far-reaching consequences being of vital interest to the American people. It is an endeavor, in the spirit of the age that is animating human thought in all parts of the world, to formulate exact knowledge, so that rules not only for safe practice but intelligent practice may be established. Engineering must ever advance towards ideal perfection, which is the perfect harmony between theory and practice, the closer union of which administers to the necessities of mankind as well as to all wealth and luxuries,—in a word, to the betterment of the whole human race. It is to contribute towards this end, as best it may, that the American Institute of Mining Engineers, relying on the wisdom and patriotism of the nation's rulers, meets on this occasion at the nation's capital, with Congress in session, to give voice to the one overwhelming need of the engineers and artisans of America.

Remarks of Dr. Egleston.

While I thoroughly appreciate the United States testing-machine at the Watertown Arsenal, and regard it as the most accurate testing-machine that has yet been built, I wish that I could say that it is complete in all respects. I not only fully appreciate it, but I have given up advising the sending of material to be tested anywhere else. It is five or six times more expensive to use this machine than any of the others, but the results which are obtained from it are, I think, perfectly reliable, and of such a character that the tests are all comparable with each other. It has proved, beyond a doubt, that the system of testing specimens of diminished area, and then calculating that the metal examined will be as many times stronger as its area is greater, is an absolutely vicious one. I am quite prepared to say, that, either from their limited size or faulty construction, most of

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the testing-machines which have been used for determining the values of the sections of reduced areas of the materials used in construction are not worth the metal of which they are made.

But while I do not mean either to under- or over-value this machine, I think that what is absolutely needed in the new departure which we hope to make is a series of tests that can be made without any testing-machine whatever. There are many dark places in the characteristics of constructive materials, especially iron and steel, that have never been cleared up. We are manufacturing these materials by the thousands of tons, and yet it is safe to say that we know very little about them. I remember very distinctly when every manufacturer believed that if sulphur was present in iron ore he must put in phosphorus, and if phosphorus was present he must put in sulphur, and that these substances when present together would exactly neutralize each other. This was held firmly as a matter of faith. It was a rude shock when some one announced that irons containing sulphur and phosphorus were both cold-short and red-short, and were cold-short or red-short in proportion to the amount of sulphur and phosphorus contained. About the year 1873 it was ascertained that it was not merely a question of the positive quantity of phosphorus contained in the irons, but of the relative amounts of carbon, phosphorus, and silicon; that with high carbon we must have low silicon and phosphorus, and that with low carbon we might have high silicon or phosphorus. This was another shock which led, however, to very important results to the manufacturers. Since that time we have ferro-manganese, ferro-silicon, and ferro-phosphorus. The whole metallurgy of iron and steel has undergone a complete revolution, who can say at what expense? And why should not a government, which derives such a large revenue as the United States does from the manufacture of metals, and is such an enormous consumer of them, investigate their properties for the benefit of the whole people?

I spoke just now of ferro-phosphorus because I have recently learned that a cast iron containing 15 per cent. of phosphorus is so soft that it can easily be cut with a knife, while that containing 4 per cent. is very hard, the hardness decreasing as the percentage of phosphorus increases. Before cast iron containing these amounts had been found, who would have been rash enough to predict such properties of a substance whose only characteristic that we knew was to make iron and steel brittle. I have several times had occasion to call the attention of this Institute to the very peculiar chemical properties of irons containing large amounts of phosphorus

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and silicon, and to point out how indispensable they were for certain uses in the metallurgy of gold and silver. Who can say that when these materials have been properly studied and experimented upon we shall not find many other commercially profitable uses for materials at which every one now looks askance?

Many of you are familiar with the careful and elaborate experiments made by Miller, Metcalf, and Parkin, for the old commission, in producing steels of given quantities of carbon, silicon, sulphur, and phosphorus. The world does not know of these investigations. So far as I know no account of them has been published. The government is in duty bound to investigate these materials, or if already lost, the experiments should be made again.

If the work of a commission, appointed by the United States, is to be commenced again, it will have not only to interest the public from a theoretical but also from a practical point of view. The public are not interested in merely scientific experiments, nor in tables of results obtained from the testing of materials by the methods ordinarily used by engineers. They do not doubt that they are valuable for some purpose of which they confess themselves to be profoundly ignorant, but they see no *practical* application of them. They do not see any direct use in ascertaining the strength of small or even of large pieces of metal or stone. They are interested not so much in knowing the factors of safety of constructive materials, as in knowing the absolute safety of the structures themselves.

I would require the commission to use the testing-machine continually; I would have it use the machine not on diminished sections, but on pieces of the full dimensions that are to be used in construction. Further than this, I would have the members of bridges and other composite structures tested separately. I would then have every kind of bridge put up and broken, the broken pieces reinforced, and the bridge again broken, and so on. It is my opinion that when bridges had been broken once or twice the best form of every style of bridge would be ascertained to be something quite different from what we now generally use, and the weight of material used in them might be very much less. I would repeat the same series of experiments for girders and trusses, the same for columns, and the same for the actual pieces used in every structure where life, health, and comfort are concerned. If the public were fully assured that this was the purpose and intent of the commission, engineers would not be obliged to ask Congress to appoint such a commission, the public would demand it.

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What I have said just now relating to iron materials should also be done for structures composed of wood, and I think that we would find in a great many cases that the structures that we are using are not only wrongly combined but are too heavy. We have been using wood since the world began. A few experiments have been made in regard to it, but very little is really known except what has been learned by certain manufacturers who have experimented upon it. For a whole year the testing-machine of the School of Mines was used to determine the strength of wooden materials. The results of these experiments were in many respects contrary to that which is ordinarily believed; yet these experiments, being made for private parties, were consigned to oblivion, and the world is no better off for their having been made.

But these structures in themselves are not the only things in which the public has a direct interest. We know that metals and constructive materials undergo fatigue, that up to a certain point this fatigue will not cause rupture, and that if the material is allowed a certain amount of rest between the intervals of fatigue it will last a much longer time than if it has no rest. There comes, however, a time when the fatigue is so great that it will overbalance the refreshment and the metal then breaks. Who knows now whether there is any possible method of ascertaining beforehand when a metal is fatigued so as to prevent disaster from rupture?

We do not know but that we are constructing at the present time our bridges, girders, trusses, etc., with such factors of safety that the metal itself may be the cause of its own destruction. Every engineer knows of the deleterious effect of superfluous material in structures which are to bear continued vibration or repeated shock. We have reason to believe that disasters from overweight of the structure occur more frequently than has been supposed. We know something about the law of fatigue, but we do not know much; we know still less about the law of refreshment. It has been well known for a long time that if metals were placed in a testing machine and pulled to a certain limit and then allowed to rest, they would bear a much greater tensile strain than if they were pulled apart at once. But we do not know the law by which this almost instantaneous refreshment takes place.

I made a calculation some years ago, as chairman of the committee to assist the old commission, that if the tests as they were to be made should prove that the quantity of materials in constructions could be considerably lessened, and yet have as great, perhaps greater strength,

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every navy yard of the government would save at least $100,000 a year. The government which can make anything like such a saving is not only justified, but in duty bound to incur the expense necessary to insure it.

Iron and steel are not the only materials, however, which require investigation. My own researches during the last eighteen months have been upon copper and a series of its alloys, and to a very large extent upon brass and cartridge metal. This last metal is of great value, and is required to resist extraordinary pressure. And what is true of this is true of nearly every metal that is spun or struck-up. In the course of these investigations I took several series of samples, selected at random from many hundreds of thousands of cartridge cases ready for use, and loaded and fired the cartridges until they could no longer be used. Many of these were useless after the first firing, some of them were fired ten times, some thirty, and some as high as one hundred and fifty times. Now I ask why should not every one of these cartridges, made of the same metal, in the same way, and with the same machinery, have stood one hundred and fifty times firing? After a patient investigation, embracing every side of inquiry, chemical, physical, and mechanical, I ascertained that the immediate cause of rupture was the starting of the more volatile metal in each of these alloys. Why should exactly the same condition cause the volatile metal to start, and the metal to become worthless in one case, after the first firing, when in others it stood one hundred and fifty firings? Those who have not looked into this question of the separation of alloys under pressure, and the different velocities of the cold flow of metals under equal pressures, have very little idea of its commercial importance. I have seen many tons of such rejected material as this in the manufactories of our Eastern States, every ounce of which was rendered useless from some such cause. I have seen hundreds of thousands of cartridges apparently good, but rendered after a few months of storage, at absolute rest, completely useless from the same cause, though they had stood the test of inspection and trial when first made. I believe that this and other kinds of fatigue are perfectly preventable, but nothing but the work of such a commission would be able to ascertain for the world at large what the means of preventing it are.

It is easy to ask why private individuals should not make these investigations for themselves. The reply is, that the same investigation, if made by private individuals, may be repeated fifty times and at many times the expenditure necessary to have the whole subject

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thoroughly investigated, and still no addition be made to the sum of human knowledge, for the results of every private investigation are kept secret. My own professional practice is full of just such investigations as these; some of them I am at liberty to speak about, but most of them are the private property of those who had them made. Most manufacturers are unwilling, and justly so, I think, that the capital which they have expended in ascertaining these facts should be used by others, and they are especially unwilling that their competitors should have the benefit of all their experiments and expenditure, when they are likely to have a large profit in keeping the knowledge to themselves. I do not think it is reasonable that any one should ask that the manufacturers who employ time, talent, and capital, in ascertaining the defects in their business, should give such results to the public for nothing. Some of them do it freely, and are to be commended for it, but we cannot blame those who do not. Just such information is, however, imperatively needed by the country at large. The public should know the facts and be able to utilize them, but it is only the General Government which can secure the talent and the money to make such experiments on a large scale, and in a thorough manner, and then distribute the information gratuitously. My opinion is, that this commission, while it should use the United States testing-machine, or other machines built on the same or other principles, should also construct for itself apparatus designed for special cases, which may or may not be used a second time; but that they should above all things make the experiments, to which I have referred, of testing all such structures and materials as affect the public security, health, and happiness, with full-sized structures; and, as I have pointed out to you, this cannot be done to a very large extent without many machines designed for special cases, which could be built at small cost, and which, in conjunction with the Emery machine, should be in constant use. The commission, if appointed by the government, should be expected to begin the work at once, and to make accessible by monthly publications, to engineers and others who wish to consult them, the results of those experiments, without theory or comment at first, and then after a time, when they have multiplied them sufficiently, with deductions drawn from them. They should fully test all of the theories which have been evolved from their conclusions, and afterwards publish them in the report to the proper department of the government, which report should be not only accessible to engineers, but distributed in such a way that the widest publicity may be given to the facts ascertained.

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Every time I have heard the old commission spoken of the United States testing-machine was alluded to in the same breath. This machine I believe to be, as I have said, perhaps one of the most remarkable and accurate machines that has ever been built, but to associate the work of such a commission with a testing-machine, or any other single tool or investigation only, is a great mistake. As I have endeavored to point out, the subject is much broader than a testing-machine, which is a comparatively small factor in the study of material upon which so many human lives are every instant depending, and which is such a large factor in the happiness and prosperity of every nation.

Remarks of Mr. G. S. Morison.

(Read by Mr. Bogart, Secretary of the Society of Civil Engineers.)

I have had considerable experience with the testing-machine at the Watertown Arsenal, having had broken there sixteen large steel eye-bars, besides quite a number of iron bars and two compression members. So far as accurate and satisfactory results are concerned, the machine is all we could ask for, and the officers who have it in charge, together with their civil assistants, are thoroughly conversant with its details, and entirely competent to make the tests required. The principal defect is that the force is very inadequate.

As the machine is arranged, the weighing apparatus is at one end and stationary, the measure of strain being carried from this to the scale-beam by the fluid in a tube so small that it looks like a wire. At the other end is placed the hydraulic press by which the power is applied; this press is mounted on a small carriage and held by two eight-inch screws about four feet above the floor, which are of course strained in compression during tensile tests, and in tension during compression tests. When the stretch of the material has exhausted the throw of the plunger it is necessary to relieve the strain, draw back the plunger, and move the carriage along, which is done by nuts turned by steam working on the large screws. Every specimen placed in the machine must be lifted above the large screws and lowered into position. To do this, crabs, running on travellers, which span the entire room, are placed over the machine, and by these the specimen can be lifted and put in place.

The actual time required to make a test depends largely on the amount which the material stretches, but it may generally be said, that for specimens which will stretch from two to three feet the

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actual time will be from two to three hours. This is, perhaps, as fast as tests of this kind should be made; but this would admit of making four tests per day, whereas, the actual work done by the machine is not much more than one test per day, nine tests, as stated by Mr. Macdonald, having consumed seven and one-half days. As the machine is now operated its actual capacity is not much more than three hundred and fifty tests of tension members per year, while it should be twelve hundred. Compression members can be more rapidly tested, as the plunger-carriage does not have to be moved. To get the full work out of the machine it is simply necessary to add to the present staff of skilled men a force of unskilled men who shall perform the different kinds of manual labor required, and get specimens ready during one test, so that the second specimen can be put in the machine as soon as the first is removed, and who will perform, after and before the regular working hours, such work as does not require the immediate supervision of the skilled men.

The actual charge for use of the machine is now eighteen dollars per day, besides a small charge for preparing the report on tests, and a charge for whatever expense is incurred in fitting the specimens. This charge is a very reasonable one, and in the case of large steel specimens, like those which have been tested for me, it amounts to about one-quarter the total expense of the test; the value of the bars destroyed, and the miscellaneous charges for transportation and the like, being about three times the actual charge for the test. In connection with a piece of work which I now have in hand, I have already had thirteen tests made, and shall have about as many more before I get through, so that the tests made for this single structure will occupy the machine for about one month as it is now worked.

As tests are now conducted, the record of tests is the property of parties for whom they are made, and special instructions have been given to prevent these tests being made public. To secure the fullest benefit of this machine all tests made ought to be published by the officers in charge for the benefit of all who take an interest in them, and the machine should be worked up to its full capacity. As the machine is the property of the General Government, even if the present charge, which is little more than the cost of working the machine, is maintained, the general public are justified in demanding that the results of its workings shall be given to them.

In the matter of the use of steel for structural purposes this machine is almost indispensable. The two points which must be con-

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sidered in introducing a new material for structural purposes are, first, its capacity for use; and, second, its ability to stand abuse. The capacity for use is measured by the elastic limit of the material, which is the real measure of strength to which the factors of safety should be applied; the ability to stand abuse is determined by the behavior of the material after the elastic limit has been passed; and while this forms no measure of the strains which may be put upon the material, it would determine absolutely whether the material is fit for structural purposes or not. A material like glass, which is destroyed as soon as its elastic limit is passed, is wholly unfit to sustain strains in construction. The old-fashioned high-carbon steels had the same character, and the material now demanded for structural purposes is one which shall stand a great distortion after passing the elastic limit and before rupture. The machine at the Watertown Arsenal is the only one now in existence which will determine these results on bars of the size which it is desirable to use in structures of such magnitude that it is important to use steel in them.

This machine has a capacity of 800,000 pounds, and in the course of my experiments I have had occasion to work it, in several instances, to nearly 700,000 pounds. When it is remembered that about two-thirds of the whole stretch is accomplished during the application of the last 5000 pounds per square inch, and that this stretch, and the reduction of section at point of fracture, are the best measures of the ability of the material to stand abuse, the importance of these tests is at once apparent. Although I have had a number of full-sized steel bars strained beyond the elastic limit in other machines, I have not yet found a machine which would break, or even develop any considerable part of the stretch, in any of the larger sizes of the bars which I have used.

When it is remembered that the cost of making steel now but slightly exceeds, and will probably soon be less than the cost of making wrought-iron, and that the elastic limit, which is the true measure of strain which may be safely applied, is about one-half greater even in the lower and softer steels than in the best wrought-iron, the importance of a complete set of experiments which will develop the ability of steel to stand abuse, and so prove its adaptability to the purposes for which wrought-iron is now used, can hardly be overestimated. At present it is considered best to limit its use to those parts of structures which are least liable to sudden shocks and irregular strains, though it can hardly be doubted that a steel will soon be made of such uniformity and toughness that it will be preferred to wrought-iron for all uses.

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Paper by Mr. Percival Roberts, Jr.

on specifications for testing iron and steel.

I DESIRE to present this evening a few notes from the standpoint of a manufacturer upon the subject of tests of iron for structural purposes; not that I have any new facts to which to call your attention, but rather a statement of a few of the objectionable features of the present modes of operation, showing the absolute necessity of important and very radical changes. At the present time, as most of you are well aware, proposals for materials are accompanied by certain specifications as to quality and tests to which the manufactured article must conform. Evolved in many cases from the inner consciousness of some one more expert in theory than in practice, we find a few of the specifications to be good, many bad, and some indifferent.

Appended are specimens of specifications of the most prominent engineers and railroad companies, which may be taken as representing the best and most intelligently framed specifications which we now have, and yet in some points scarcely satisfactory, owing to misunderstanding of tests as now made. To show the very varied opinions held as to proper quality of iron for bridge-work, I give the tests of two lots of iron made by inspectors with the results, which were referred to the maker with the following comments:

Lot No. 1.

Test of Iron for Eyebars.

Size.	Reduced area. Per cent.	Elongation. Per cent.	Breaking load.
$4'' \times 1\frac{3}{8}''$	26	25	53,500

Bent 120° around $1\frac{1}{2}''$ bar with fracture.

Size.	Reduced area. Per cent.	Elongation. Per cent.	Breaking load.
$5'' \times 1\frac{7}{16}''$	24	24	48,320

Bent 110° around 2″ bar. This iron should bend 180° without fracture, and is therefore rejected.

Lot No. 2.

Test of Iron for Bridge. All measurements taken upon a parallel section of 10″. *Iron for tension members.*

Size.	Breaking load per square inch.	Elongation. Per cent.
$1\frac{5}{8}$	49,500	20
$1\frac{1}{2}$	51,600	27

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Size.	Breaking load per square inch.	Elongation. Per cent.
$3\frac{1}{2} \times 1$	49,500	20
$3\frac{1}{2} \times 1\frac{5}{16}$	48,320	20.5
$3\frac{1}{2} \times \frac{1}{2}$	48,000	13.1
$3\frac{1}{2} \times 1$	48,000	25

The bar-iron was all too soft, hence lacked strength. Tests showed this; they bent 120° without fracture.

From the above we may see the very different opinions of engineers with regard to the qualities suitable for structural material.

Again, to illustrate the very peculiar position in which manufacturers are placed by this conflict of opinion, let me quote from the charge of Judge McKennan to the jury in a case brought before the United States Circuit Court, growing out of a condemnation of material furnished by the Messrs. Atkins, of Pottsville, to the Edge Moor Iron Company for the New York Elevated Railroad. I quote as follows: "There is no doubt about the fact that this iron was to be used in a structure of a particular character; that it was a particular kind of iron, and that certain qualities were essential to the value of it in such use. It will hardly be said that a man who was making a contract for angle iron of certain dimensions, and was told that it was to be used in a particular construction, such as this, for instance—over which it was to bear heavy weights, over which locomotives and passenger trains were to be carried—it would hardly be fair to assume that the parties intended that iron which would be suitable for use in a bridge over which people were to walk merely, was intended. Therefore, it is that the rule which I have stated is founded upon sound common sense; that where parties come together and make a contract in reference to a particular thing, and they both understand that it is intended for a particular use, that something which is not at all adapted to that use is not to be supposed to have been the subject of the contract between the parties. . . . . In a bargain and sale of an unmanufactured article, which the seller is informed at the time of the contract is intended for a special purpose, there is an implied warranty that the article to be furnished is fit for the special purpose intended by the buyer. In such case the buyer necessarily trusts to the judgment or skill of the manufacturer. . . . . The law implies a warrant on the part of these plaintiffs that the iron furnished by them under their contract should be adapted, in quality and otherwise, to such intended use; . . . . I do not understand that there is a serious contest here as to the quality of this iron. It was *merchantable iron.*"

Here we have it distinctly set forth, that there being no written

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or express agreement between the parties as to the quality of the material, it must be furnished suitable for its intended use. But who is the judge of its fitness? What is the criterion of its quality when we are dependent upon a standard as shifting as opinion, without proof, can make it?

To illustrate once more a difficulty which at present occurs, I give in the accompanying table a memorandum of tests made upon some flat 12″ wide bars which were intended to meet requirements of Pennsylvania Railroad specifications, namely: Ultimate tensile strength, 46,000 lbs.; elastic limit, 23,000 lbs.; stretch, 15 per cent. in 8″. Two bars 12″ × ¾″ and one bar 12″ × ½″ being taken at random from a large number, a piece 10 feet long was cut from each one and sent to Watertown Arsenal. From each one also a piece 16″ long was taken, and divided up the centre, half being sent to Fairbanks, and remainder retained at the Pencoyd Iron Works. From each of these pieces, namely, 6″ × ¾″ and 6″ × ½″, five test-pieces were cut, being about 1″ wide, and tested with results shown in following table:

Tensile Tests of 12*-inch Iron Flat Bars.*

	Marked.	Area in square inches.	Elastic limit per square inch.	Breaking load per square inch.	Stretch in 8 inches. Per cent.	Stretch in 10 inches. Per cent.	Stretch in 80 inches. Per cent.	Contraction of area. Per cent.	Tested by
12″ x ¾″	1	.6048	30,588	46,630	10.94				Pencoyd.
	2	.7000	29,785	44,714	8.59				"
	3	.7000	30,678	46,285	8.59				"
	4	.6797	28,240	46,270	13.27				"
	5	.6769	28,000	42,376	6.25				"
	937	.7590	25,955	39,223	10.37				Fairbanks.
	832	9.00	23,890	46,544		16.2	15.2	23.0	Watertown Arsenal.
12″ x ¾″	1-1	.5831	30,703	47,890	12.50				Pencoyd.
	2-1	.7548	30,990	45,753	8.59				"
	3-1	.6438	29,540	47,360	9.37				"
	4-1	.6453	28,800	47,700	15.62				"
	5-1	.7474	29,116	44,076	9.37				"
	936	.7600	27,632	47,342	22.37				Fairbanks.
	1833	9.04	25,660	46,270		21.0	16.5	19.7	Watertown Arsenal.
12″ x ½″	1	.5226	27,675	42,624	9.37				Pencoyd.
	2	.5512	31,397	42,831	7.02				"
	3	.5353	31,600	43,551	8.59				"
	4	.5194	30,687	40,173	7.02				"
	5	.5459	30,767	43,406	8.59				"
	938	.5360	28,638	43,208	9.25				Fairbanks.
	1831	6.06	26,400	41,584		14.1	7.2	21.6	Watertown Arsenal.

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In these results we see a great want of uniformity. By the Watertown tests the bars would be accepted, while by the Fairbanks tests two would be rejected. Some pieces, by the Pencoyd test, would be accepted, while others, taken beside them, would be rejected. The elastic limit in both the Fairbanks and Pencoyd results is probably too high, owing to the method of observation. The $12'' \times \frac{1}{2}''$ bar at Watertown broke through a blister which opened at 31,000 lbs. per square inch, which accounts for the low tensile strength of this bar.

We have, as it were, tested chips, and from them deduced the strength of timbers. Small samples of one square inch area or less, and a few inches long, have given us all we know of sections for structures of many times that area and length. It may be well laid down as a law, that in bars of iron, whether round, flat, or square, the element of non-uniformity varies as the square of the sectional area. It is generally considered that iron of good average quality is capable of sustaining an ultimate stress of 50,000 lbs. per square inch. A bar of a sectional area of one square inch should, and no doubt will, stand the above, but we err in concluding that a bar of six square inches will sustain a corresponding stress. There is one point which cannot be too strongly urged upon all those who employ wrought-iron for structural purposes, and that is to pay especial attention to the shape of the section upon which they are calculating strains. The bar of one square inch, whether round, flat, or square, will give probably the same result, but put the same quality of iron into a wide, thin plate, angle or channel, and a very different result may be obtained. It is, I think, much the same as if the material of a rope was placed in such a form that all the fibres did not sustain an even share of the strain, and consequently, some being overtaxed, yielded first, causing rupture at a lower stress than had the fibres all borne an equal proportion of the load. We pay too great attention to ultimate breaking strength at the expense of the other far more important qualities of elastic limit, reduction of area, and stretch. For if we strain a piece beyond its limit of elasticity it is only a question of time when its failure will occur.

I have very hurriedly and imperfectly shown a few of the disadvantages under which both the buyer and the manufacturer labor at the present day, owing to the methods of testing now employed. Where shall we look for a remedy? I answer that government testing-machines, such as the one now at Watertown, capable of testing the largest sections of iron and steel, both rolled and forged, should be

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erected at the principal manufacturing centres. Tests could then be made quickly, as the material is furnished by the mills. The testing also will be in the hands of competent persons, who, engaged in this work alone, will be much better fitted to conduct tests than those who now in many cases undertake them. Upon these machines let experimental researches be conducted by properly appointed commissioners, among whom I deem it very essential that the manufacturer should be represented. To the engineer no doubt belongs the determining of strains and the calculation of parts, but very many questions will arise in the course of these investigations which can best be answered by those thoroughly acquainted with the practical details of manufacture. As one of the results of these researches I would suggest the framing of a *standard* set of specifications for tests to which iron and steel for structural purposes should be subjected. We have our standard weights and measures, why not our standard tests? I believe by so doing a better manufactured article would be obtained, as the mixtures of iron would not be continually changed to give here a little more elasticity, and there a trifle less stretch. This matter of government action is one of vital importance. Year by year the employment of metal in place of wood for structural purposes is increasing in an enormous ratio, and we are ignorant, very ignorant, of the qualities of the metal we are using, and the strains which it will sustain. The thrilling story of a bridge disaster bears more eloquent testimony to this fact than any words of mine. It is not in the interest of any one section of country or class of people that the aid of the government is invoked. The expense to be incurred in these investigations is far too great for any individual corporation to bear, and the knowlege to be gained belongs to the nation. The citizen of San Francisco who travels to New York is as much interested in the safety of each bridge upon his route as he who lives beside it all his life. A beginning has been made, the testing-machine now in operation at the Watertown Arsenal is a grand monument to American engineering, and is it to be but labor wasted? I feel that this whole matter, if placed before Congress in its proper light, would result in prompt and intelligent action.

Remarks of Mr. William Metcalf.

One point of vital importance has not been touched upon this evening; it is the necessity of having a history of the mode of

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manufacture of material tested, before an engineer can make safe and intelligent specifications.

When a person buys material of a known brand, the manufacturer will properly decline to say what raw materials he used, their proportions, or the way in which he worked them, because his competitors would seize upon such facts and use them to his disadvantage. For this reason all private records of tests, either of manufacturers, constructing engineers, or others, are seriously defective.

There is at present no way for an engineer to learn how to specify the way in which his material shall be worked, based upon any well-known general principles, and there is, consequently, no way for him to know, within bounds of reasonable certainty, the quality of his material except by testing each piece to ultimate rupture. To illustrate: the only gun that burst in proof of several thousands made at the Fort Pitt Foundry, gave in tests: specific gravity about 7.26; tensile strength about 35,000 pounds per square inch. I speak from memory, but the figures are very nearly right. This gun was thus about perfect in physical tests, it was a sound casting, showing no porosity or flaws, and it was impossible for the inspecting officers to know the cause of failure. The founders knew exactly the cause of the trouble, and no more such guns were made. Again, in the case of the large steel anchor-bolts for the St. Louis bridge: some of them broke at from 28,000 pounds to 35,000 pounds per square inch, and test pieces from these broken bolts gave a tensile strength of about 115,000 pounds per square inch. The engineers and contractors were thoroughly puzzled until a friend told them that the steel was undoubtedly good, but that internal strains had been set up in the manufacture, and that it was probable that careful annealing would remove the trouble. I do not know what was done in this case, but after that time there were no more failures of that sort.

A commission, such as is now proposed, could go to a manufacturer and ask him to make certain pieces from given raw materials to be worked in specified ways, a complete history of the manufacture to be kept and sent to the board with samples of raw, partially worked, and finished product. No person would object to doing this, as it would not involve the giving up of any trade secrets; and in this way, and this only, can engineers ever learn to avoid the most serious dangers to which they are now exposed.

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Communication from Mr. C. P. Sandberg.*

(Sent to the Secretary in manuscript subsequent to the Washington Meeting.)

Having been occupied in inspecting and testing iron and steel these twenty years in England, and previous to that having served on the Board of Iron Masters in Sweden, I have naturally been very much interested in the subject of the use of steel for structures. I regret that I can offer but comparatively small experience on that head, having had principally to do with steel for railway plant and rails, but granting these to be a kind of "structure," and also that steel for rails has similar duties to perform in many respects, and is generally manufactured in the same way and at the same works as steel for structures, properly speaking, I may be entitled to offer an opinion on the use of steel in construction. In a paper recently presented to the Institution of Civil Engineers in London, Mr. Ewing Matheson has recommended that the Board of Trade rules should be amended so as to allow of a maximum straining of 8 tons per square inch instead of 6½ tons. But it is equally necessary to fix the amount of ductility or elongation of the metal for such a strain as 8 tons. Strength and ductility should always be spoken of together.

Mr. Matheson says that steel can be manipulated in the factory in the same way and with the same tools as are used for iron. This can only be granted for mild steel, for hard steel would be spoilt by the rough mechanical treatment which iron can stand, such as punching, for instance; and the remedy for regaining the strength lost by punching hard steel, viz., annealing, cannot always be applied. Nothing proves this fact better than the punching of steel rails of considerable hardness, which caused fractures at an early period of steel-making, and which resulted in the stipulation for *drilling* instead of *punching* the bolt-holes, which had been formerly applied to iron rails without any damage. In fact commissions to establish standard tests are now working on the Continent, principally in Germany, where

* It is an interesting coincidence that about the same time of the discussion at the Washington meeting of the Institute of "Iron and Steel considered as Structural Materials," the subject of "Steel for Structures," introduced by a paper by Mr. Ewing Matheson, was under discussion in the Institution of Civil Engineers in London. The remarks herewith presented to the Institute are, in the main, the same as those made in the discussion of Mr. Matheson's paper, but as this discussion may not be seen generally by my fellow-members of the American Institute of Mining Engineers, I desire to contribute the results of my experience also to the Transactions of the Institute.—C. P. S.

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the government, having taken possession of the chief railways of the country, are laying down laws almost impossible for the makers to fulfil. It is only a fortnight since the question was under discussion at Berlin, where a paper was read by Dr. Wedding (of which a résumé is published in a recent issue of *Stahl und Eisen*), under the title Classification and Specification for Iron and Steel.

The main point of the German specification is that every charge or blow should be tested for tensile strength, but not accepted by the inspector at the works, but by the railway directors themselves after their own testing, by which system great delay and other inconveniences in the execution of the order are caused, resulting sometimes even in the rejection of large quantities at the final inspection on arrival at destination. This the makers naturally think unreasonable.

An illustration of the tensile-strength test being applied to railway structures of steel, as the principal guarantee for safety, with neglect of a test for concussion or impact, is just at present to be seen in Germany. The railway authorities complain of more fractures there, and have in fact fixed a price for the best invention for holding a broken tire to the wheels, so that it will not fly and cause accidents; and they state themselves that in cold winters heavy breakages of the steel occur in rails, axles, and tires, notwithstanding that their steel has undergone test for tensile strength. On the other hand the makers complain bitterly against this mode of testing, as being slow and costly. On analyzing the steel it is generally found that silicon and phosphorus are present in large quantities, but as the carbon is low, considerable tensile strength and elongation can still be obtained. What better proof can be needed on a large scale of the inefficiency of the tensile-strength test of steel for cases where concussion is to be endured? I have inspected rails with satisfaction for countries with far more rigorous climates than Germany, for instance Russia and Sweden, using the drop test only, neglecting the tensile strength.

In America the control and inspection of the quality of steel is overdone in another direction, viz., by chemical analysis, so that steel, even for rails, is now nearly always chemically analyzed and the composition stipulated in contracts. I have had ample experience to enable me to say that both these methods are impracticable as proposed in Germany and America for rails, and that a strict inspection with the heavy falling or drop test at the works is quite sufficient both for economy and safety. But working particularly for

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America, I have been obliged to accommodate myself to the stipulations, and I have analyzed steel, both for rails and for blooms, in conjunction with makers. I have made in my own laboratory more than 800 analyses, during the last twelve months, of steel from all the principal makers in Great Britain and Germany; and have established a system of combined mechanical and chemical testing, which is at least workable or practical as a sort of combined control, running regularly with the production, without interfering more than is necessary with the execution of the contracts.

This system consists in the resident inspector at the works testing the product mechanically, generally with the falling weight. Then borings are taken from the very spot where the steel has been tested, and these borings are divided between the makers and myself for chemical analysis. It is a great satisfaction for me to state that the results almost invariably agree. This is the very best proof of how well chemistry is now applied at almost every steel works, and reflects great credit upon the Royal School of Mines, where most of these chemists have received their training, under the guidance of Dr. John Percy, who has also greatly contributed to our knowledge of steel-making processes through his works on iron and steel.

The suggestion of supervision of the whole manufacture, in order to see that there are used suitable ores, pure fuel, and material, through the various processes, I would venture to disapprove. I think any interference with the maker in this respect would be almost worse than the American or German methods of testing the ready product; and although the maker should give every facility at the works to execute specified tests, he should at least be left free in choosing his own raw material and the mode of working it, so as to attain the desired end. I have always held that in testing an article the *modus operandi* should, if possible, be adapted to the functions it has to perform in practice, such as tensile strength and ductility for structures of dead load, density and homogeneousness for abrasion, tenacity for concussion, etc.

Bridges having to support trains running with anything like speed are exposed to concussion, therefore the material in them should be tested for concussion, just as are rails and axles and tires. This is all the more necessary, as steel, with an excess of silicon and phosphorus, will roll apparently well and even give pretty good results in tensile strength if the carbon is at the same time low. Such steel would, in rails, be almost superior to the pure steel. I have had, for the purpose of comparing wearing results, Bessemer steel rails

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made in Sweden of their pure material, laid down here in London, and found them not so durable as those made in England, notwithstanding the latter were more impure. Happily, however, for the impure steel rails, there is but little work put on them before they are laid that is apt to impair their strength. But very different results might be obtained if the same material were used for structures in which it had to undergo the barbarous treatment of punching, slotting, and bending cold, before coming into its place. It would be better if the deficiency in strength was discovered by fracture occurring in any of these operations than if it stood them and afterwards failed as a member of the structure.

But in large practice only a small percentage, taken at random, can be tested, and the inspector will, of course, have to rely upon the bulk being like the sample tested, or, in fact, upon the regularity of the production. Now there has been no doubt great progress made in steel-making as regards regularity, but perfection is still not reached, as every engineer knows, without perhaps knowing the reason. For instance, in the Bessemer process it is necessary that the proper raw material should be used as far as the phosphorus goes (which makes steel cold-short, and therefore should not be used in higher degree than what is anticipated to remain in the steel). Silicon is a more frequent cause of irregularity, for even with the uniform contents of silicon in the pig-iron used, the heat during the blow decides whether the whole of the silicon goes into the slag as silicate of iron, or only a part of it. There is no sign, excepting the heat of the charge, to guide the maker when the silicon is out, as there is with the carbon, consequently the amount of silicon in the ordinary Bessemer steel may vary considerably without any sign in the process to indicate it; and, admitting that it is a hardening substance, particularly when it amounts to 0.25 per cent. or more, it is the most prevalent cause of irregularity in the hardness of Bessemer steel.

I pointed this out in a paper read before the Institution of Civil Engineers fourteen years ago,* and it seems strange, with all the advancements in Bessemer steel-making, that such a cardinal fault should not have been overcome in that long time. Until there be a means of knowing how much silicon is blown out (like the carbon), before the steel is tapped, I fear the regularity of Bessemer steel will always be more or less uncertain. Granting that it has lately become more regular through using less silicious pig to start

* Minutes of Proceedings, volume xxvii., page 408.

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with, and maintaining a more uniform heat, still one blow might give only a trace of silicon, and the following one 0.50 per cent., and even 0.75 per cent. with the same carbon and other constituents, and there is no means of knowing that this is the case from any sign in the working of the process until the product is tested mechanically and chemically. Blowing a little longer will not always reduce the silicon, but rather cooling the charge by letting it stand, or throwing in cold crop-ends or ingots so as to obtain a semifluid bath, which allows the slag to be intimately mixed with the metal; when the metal is quite fluid, and the slag flows on the top, you may blow a long time without any silicon going out.

It is almost certain that the carbon in the molten pig iron in the Bessemer vessel is oxidized from the action of the slag and not from the oxygen from compressed air. In fact the same chemical action takes place in the oxidation of carbon and silicon as in the puddling or in the open-hearth process, as explained by Professor Sefström in the School of Mines of Fahlun, forty years ago. Hence the necessity of the thorough admixture of the metal and slag, which can only exist in the semifluid state of the metal, before any combustion of carbon or silicon can take place. I have only mentioned this to show one of the principal difficulties which makers have to contend with in obtaining regularity in the hardness of Bessemer steel.

On the other hand, experience shows that a certain amount of silicon is absolutely necessary to give solidity to the ingot, and judging from experience, derived from the comparison of hundreds of analyses with the ordinary inspection and mechanical testing, I would state that 0.10 per cent. is the minimum amount of silicon which should exist in solid steel ingots suitable for rolling into clean rails, angles, or any ordinary flange sizes, and that anything under this amount, as, say 0.04 per cent., according to Dr. Dudley's formula for rail-steel, gives blistering ingots and double the amount of wasters in the finished article. Silicon is needed to absorb the oxide of iron, which otherwise causes cracks in rolling, produced by overblowing.

The best proof of this statement is, that the only complaint which I have had of blooms inspected for American railmakers, has been that they are giving more wasters, where the silicon is low, through cracks in rolling. I have also had the same experience in my own rail inspection when the steel has less than 0.10 per cent. of silicon.

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Admitting that each of these substances present in the steel in amounts beyond the average variation above stated is exceptional, and that some makers, and even countries, are producing a purer and more regular steel than others, still these figures will speak for themselves as to the regularity of the composition of Bessemer steel. They show how much more is to be desired in this direction, and also how great variations in chemical composition can be tolerated without any risk. This is especially true of rails, for which these analyses have been made, in connection with mechanical tests, which the rails have all withstood in sufficient degree for safety.

These results indicate greater regularity in the Siemens than the Bessemer steel, probably because of the greater time allowed for testing before tapping. This also applies to basic steel, which is comparatively free from silicon, as is also Siemens steel.

As Mr. Matheson suggests that all possible modes of testing should be applied to reach a proper classification of the metal, and to obtain the required degree of hardness for each particular purpose, I am surprised that he has not mentioned the chemical mode of testing for steel in structures, which I have been forced to adopt for rails a great deal more than I desire, and even more than I think necessary for that article. But I cannot deny that chemistry, applied in conjunction with mechanical testing of steel, has thrown a remarkably lucid light upon the whole subject, in explaining why such and such phenomena occur; and as chemistry, from the beginning of steel-making, has been an assistance, and is still a great assistance to the maker, it may be of equal value to the engineer or consumer. But there is the danger of overdoing it, as has been done in America, by stipulating fixed formulas, which hardly any one can fulfil, and which are not at all necessary.

In conclusion, I wish to say that, while the American steel-makers, as well as those in Germany, unite in suggesting practical normal methods to engineers, and in resenting any undue and impracticable modes of testing steel, those of Great Britain have not done so yet. This is the more remarkable, since their Iron and Steel Institute, as a body representing the steel trade, affords them every opportunity of suggesting normal or standard methods, which might be of great practical value to producers as well as to consumers of the new metal steel.

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necessarily absorbed a large portion of their labor and funds. Even these, however, were rather of the nature of geological reconnoissances than of surveys properly so-called—the conditions of the work demanding that a given superficial area should be covered each year, without allowing time for complete and thorough investigation of any particular class of phenomena or series of deposits. Their labors had nevertheless furnished an adequate knowledge of the general geology of the great Cordilleran system in the United States, as well as general topographical maps of an area sufficient to serve as a basis for more accurate and detailed studies, which might occupy, for a number of years to come, all the force which could be employed with the funds Congress would probably be willing to appropriate.

Therefore, instead of continuing reconnoissance work over the remaining unexplored area, it was decided to make detailed monographs of particular districts in the region thus partially known, for the purpose of illustrating geological phenomena of special interest; and thus give time for topography to precede geology, as it properly should, in the as yet unmapped regions.

An important change in the manner of carrying on the geological work, introduced by Mr. King, was that of dividing the country into departments or divisions, over each of which should be placed a geologist-in-charge with an office at some central point, to whom, under the general supervision of the director, was intrusted the entire responsibility of planning and carrying out the work in his division, and the choice and general direction of his assistants. This change was favorable both to efficiency and economy, since by it the annual expense of transferring large parties from Washington to the field was avoided; and the employés, becoming more and more familiar with the character of their particular district, could work up their material in the immediate vicinity of their field of labor, and would be enabled to do more rapid, and at the same time more accurate work.

In pursuance of the idea that more attention should be given to the practical application of geology to the development of mining industry, the work of the survey was distributed under two main heads—General Geology, and Mining Geology; which, while independent, should mutually assist each other. In time it was intended that in each division a distinct corps should be occupied in each of these branches, whose combined labors would result in giving us not only a geological map of the whole country, but an intimate ac-

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quaintance with its mineral resources, and some definite knowledge in regard to the vexed question of the origin of ore deposits. In the two field-seasons that have elapsed since the adoption of this programme, with the limited funds appropriated for the use of the survey, necessarily but a small portion of the work contemplated has been accomplished. Nevertheless a number of monographs are now in process of publication, which will, it is hoped, prove the wisdom of the programme above sketched. Their possible field of usefulness will certainly be enlarged by the fact, that they will be procurable by all who desire them, at the cost of publication.

The work of the mining geologists of the survey is that in which the members of the Institute will naturally feel the most direct interest. As a brother mining engineer, I feel that it may not be inappropriate for me at this time to give some account of the manner in which that portion of the work intrusted to me has been carried out, in accordance with the above general programme, and to offer to your consideration and criticism my idea of the principles and aims which should govern such work.

The mining geologists of the Government should, it seems to me, bear to the mining engineers of the country a somewhat similar relation to that which the latter hold to individual owners, and the mining public at large. The duty of the mining engineer toward his employer, the actual or prospective owner of a mining property, is to place before him in an intelligible manner the character, mode of occurrence, and probable quantity and value of the mineral deposits which his property may contain, and the best method of utilizing them. The duty of the government mining geologist, whose field of observation is wider, and whose facilities for carrying on work are greater, differs only in this, that his views should be more comprehensive and his study should take in the general interests of a group of mines or of a whole mining region, rather than of a single mine. In neither case, however, can trustworthy results be obtained except they be founded on a sound and accurate knowledge of the geological structure of the region in which the deposits are found.

In coal deposits, it is true, the necessity of a geological basis for reports has long been generally recognized. But, in respect to metallic deposits, how many of the hundreds of mining reports that are made every year in this country have any foundation of actual geological data? But few, indeed. I have been forcibly struck by this fact, in the course of my investigations, when I have endeavored

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by the study of reports on regions I had not yet visited, to obtain some definite idea of their geology.

Nor is this true only of this country; it applies also, though perhaps in a less degree, to older countries. Look even at the classical work on ore deposits of our respected Von Cotta, which is a compilation, made by a man whom we all acknowledge to be thoroughly competent, of the best scientific data obtainable at the time he wrote. How little satisfactory information can be gathered from it of the actual geological relations of the deposits described. Why is this? And in what way should it be remedied? If we ask the mining engineer why he has not given more geology in his report, his answer will probably be: First, that nothing had been published on the geology of that region; second, that the persons by whom he was employed desired practical results, not theories.

Of the two reasons thus given the first is certainly a valid one, and the want of published data is one which it should be the first duty of the Geological Survey to supply. The second is the expression of a prejudice, unfortunately too common in the public mind, in favor of practical as opposed to scientific mining—a prejudice for which mining engineers as a class are partly responsible. Fortunately this prejudice is gradually disappearing. Ten or fifteen years since it was so strong that the fact that a man was a graduate of Freiberg, or other European mining academy, was almost sufficient to bar him from employment in a Western mine; while, to-day, in Leadville, among the most successful miners and metallurgists, are found prominent the names of graduates of Freiberg and other European schools, such as Eilers, Meyer, Grant, and others.

Nor is this prejudice confined to untechnical men. Many mining engineers, while freely admitting the necessity of a geological basis for determining the value of coal, iron, petroleum, and allied deposits, consider it at best in the nature of an ornamental or decorative addition to a report upon metallic mines. In my opinion, however, there is no inherent reason why, with sufficient study and investigation, the geological relations of metallic deposits should not be determined as accurately as those of coal and iron. The subject, it is true, presents greater difficulties, and in the rapid advance of geology at the present day, the geologist and the mining engineer have been pursuing somewhat divergent paths—the former confining himself more and more to special branches of theoretical study, and the latter to the technical and mechanical side of his profession. In Prosepný's excellent work, *Archiv der Geologie*, a chapter is given,

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[*Geologie und Bergbau in ihren gegenseitigen Beziehungen*], deprecating this tendency, and outlining in some detail the official work done at present in both branches by civilized nations.

It behooves us, then, it seems to me, not only as geologists, but as mining engineers, to give greater importance to geological structure in our reports and papers on metallic mines; and this not only for the purpose of removing the above-named prejudice, but for the sake of accumulating matter which shall, in time, afford us the means of rendering to ourselves as satisfactory and definite an idea of the manner of the formation of metallic deposits, as we have at present in the case of coal.

The work upon which I have been engaged during the last two years, at Leadville, will shortly appear as a monograph of the geology and mining industry of that district, and is one in which the practical value of a knowledge of geological structure is peculiarly striking. With the general outlines of this structure you are all, doubtless, more or less familiar. The mines are situated on the west slope of the Mosquito Range, near the head of the Arkansas River. Their ore is largely argentiferous galena and carbonate of lead; a so-called contact deposit occurring between limestone and an overlying eruptive rock, generally called porphyry, but which some have wrongly classed as rhyolite. The principal mines of the district may be divided into three groups, called, from their location, those of Iron Hill, Carbonate Hill, and Fryer Hill. In the two former, which are simply shoulders on the same mountain spur, situated one above the other, the geological structure is comparatively simple, and is generally well understood. The ore is found at or near the surface of the limestone, which in either case dips gently to the eastward, near its contact with the overlying porphyry; and the great fault plane along which the movement has taken place, by which the beds in Iron Hill have been lifted up, a thousand feet or more, from the position they originally occupied as a continuation of the Carbonate Hill beds, has been actually laid bare by numerous shafts and winzes.

Still, evident as this structure might appear to the mind trained to geological reasoning, when questions of conflict of title, involving the right, under the United States mining laws, to follow the vein in depth, were brought before the courts, mining experts, many of whom called themselves geologists, were not wanting who were ready to advance other theories of structure in support of the claims of the companies by whom they were employed, and these theories

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seemed to find favor with juries in inverse ratio with their probability from a scientific standpoint.

To the west of the outcrops of the easterly dipping beds on Carbonate Hill, limestone and ore were found beneath the porphyry, which seemed to some to indicate the existence of a much-desired second contact.

On Fryer Hill, where the richest deposits of all were found, no such simple structure was evident, since no limestone was found to underlie the ore beds; and, as the whole hill was covered to the depth of 75 to 100 feet with a sort of boulder drift, no outcrop could be found to indicate the lines of structure or the succession of formations.

My first visit to Leadville, which was in the fall of 1879, showed me that the structural problem here presented was one of intense complication, which could not be satisfactorily solved without the aid of elaborate and most accurate maps. Moreover, I saw that the immediate vicinity of Leadville was a region of intense metamorphism or internal alteration of the rocks as well as of great complication of external structure, and where, owing to the great accumulation of detrital material on the surface, but few actual outcrops could be seen; that it would be an almost endless labor to determine accurately there the horizons of the sedimentary beds, or the structure of the eruptive masses; and that the key to these points must be sought near the crest of the range, where, in the great glacial amphitheatres, rock sections several thousand feet in thickness were exposed on every side. Owing to the great altitude of the region, however, it was not until the following summer that this portion could be explored. Meanwhile, with my assistant, I was occupied in examining underground workings, and gathering all the data possible, without, however, getting more than an inkling of the actual facts, which a later field study of six short weeks in the surrounding region made clear.

These were, *first*, that the ore deposits of Leadville occur either at the surface, or in bodies extending from the surface downward into the mass of a bed of blue dolomitic limestone, about 150 to 200 feet in thickness, belonging geologically to the base of the Carboniferous group. This horizon it was possible to recognize unmistakably in almost every instance, not only by its lithological characteristics, but by the succession of beds, only about 400 feet in thickness, which occur between it and the underlying crystalline schists and granite of the Archæan. *Second*, that the eruptive rocks, mainly por-

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phyries of a pretertiary age, occur in immense intrusive sheets, so regularly interbedded that they form an integral part of the sedimentary series, and have been faulted and folded with them; that the dike form of eruptive rock, although not uncommonly seen along the cañon walls, is of subordinate importance, and, as a rule, of later date than the intrusive sheets, since they cut across these and their bounding sedimentary beds; that the intrusive sheets had evidently spread out between the beds from certain centres of eruption, following by preference a definite horizon, but sometimes cutting across the beds to another horizon, or splitting up one bed or formation into two or more distinct sheets; and that, since these intrusive sheets have partaken of the movement of faulting and folding to which the sedimentary series have been subjected, they must have been erupted prior to this movement, which took place at the close of the Cretaceous, and, therefore, when the sedimentary series still occupied an undisturbed or horizontal position, and very probably while they were still covered by the waters of the ocean. *Third*, that the ore-deposits, and the vein material or gangue inclosing them, which is, in Leadville, silica, iron, and manganese, with an admixture of clay from the decomposition of the porphyries, are a direct replacement of the limestone in place, and that they occur either on the upper surface of the limestone, or, when they do extend down into it, the bodies wedge out at the bottom and are connected with the surface; that, therefore, the generally given origin of ore-deposits, as coming from some unknown source below, does not hold good in this case, for they evidently came from above, in an aqueous solution, and were deposited from percolating waters. *Fourth*, that the difference between the ore-deposits of Fryer Hill and those of Iron and Carbonate Hills, is one of degree and not of kind; that here the main porphyry sheet had divided into two or more, and besides the sheet above the ore horizon there was one below it, and sometimes one in it, splitting the limestone into two or more parts; that there was a nearly vertical dike of another variety of porphyry cutting across the beds; that the beds were compressed into a series of shallow folds, which had been eroded in such a manner that from the south and west portions of the hill the ore horizon had been entirely removed; that over the greater portion of the hill the replacement action had been so complete that the Blue Limestone horizon is represented by vein material, with here and there small bodies of dolomite sand, and detached blocks of dolomite, as the only relics of the original limestone bed.

The above somewhat bald statement of a few of the many inter-

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esting results of the work in which I was engaged at Leadville, is given here simply to aid in illustrating, in this particular case, the point upon which I have been insisting above; viz., the practical importance to the mining engineer of a knowledge of the geological structure of any region in which he may have to report upon or manage a mining property.

The value of this knowledge may be further illustrated as follows: *First.* By an acquaintance with the geological horizon, and the succession of beds above and below that horizon, the engineer is enabled to determine upon examination whether this horizon exists on his property or has been eroded off; in the latter case he need spend no money uselessly in searching for it; if it *is* there, he can determine more or less exactly, according to circumstances, its position, and how he must follow it. Whether he has published geology to tell him what this succession is or not, it will only require a day or two's examination of some of the many sections exposed along the cañon walls outside the district to familiarize him with the succession and lithological characteristics of these horizons, and this examination he should make under any circumstances, as written descriptions of rocks can never be as satisfactory as personal observation. *Second.* With regard to the eruptive rocks, considerable familiarity with lithology, and, very probably, actual microscopical study of their sections, may be required to determine their ultimate character, but a few days' study along these same cañon walls would suffice to show the main facts mentioned above, viz., that they occur rather as interbedded sheets than as dikes, and it would then be a fair deduction to make, that around Leadville itself the same conditions obtain. He would not, therefore, suppose that each body of porphyry he saw was a dike cutting up across the beds from below, but, on the contrary, would suppose it to be an interbedded sheet, unless he had actual evidence to the contrary. *Third.* The determination of the manner of occurrence of the ore-bodies, and still more, their probable origin, would require a somewhat extended observation of the various underground workings of the district, and these questions might, at first sight, seem to be rather of speculative or theoretical than of practical value. Their practical value in the present instance is, however, readily apparent. The fact that the ore comes from above, and not from that unknown and often called-upon source in the depths, affords good reason for not sinking deep shafts or running long tunnels in hope of striking as yet unknown ore-bodies of great value, the chance of which is so attractive to many investors in the great lottery of mining.

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Work of this kind involves, it is true, a great deal of time and labor on the part of the mining engineer; no report of any geological value can be dashed off after a visit of a day or two, unless the facts are all known beforehand. Nor can generalizations of value be deduced from the examination of a single mine in a district. But the large fees which mining companies are not unwilling to pay, in these days, justify considerable labor on the part of the mining engineer; and if he wishes to take the first rank in his profession, it is necessary that he should do conscientious work. Let him avoid, however, the opposite extreme of expecting to produce, in his report, a universal theory of all ore deposits from observations based on a single district, since such hasty generalizations stamp him at once as untrustworthy or visionary.

The class of deposits, of which those in Leadville may fairly be considered the type, is one, it is true, in which the structural relations of the surrounding rocks play an exceptionally important part; but this very class, which is essentially notable rather for the quantity than the quality of its ore, is destined, now that the West has been rendered somewhat more accessible by railroad, to become one of the most important producers. Up to within a few years, their value was scarcely known at all. Now that the prospector has become practically acquainted with them, they are more diligently sought for; and their extent is probably very great, since every day brings report of fresh discoveries. Those of Lake Valley, New Mexico, so well described by Professor Silliman in his paper just read,* are evidently an important group of these deposits; and it is interesting to note that while the iron vein material in the wet region of Leadville is a hydrous oxide of iron, in the arid mountains of New Mexico it is the anhydrous oxide of iron that forms the gangue of the silver and lead ores.

During the time that I was occupied at Leadville, Mr. G. F. Becker was making an exhaustive study of the famous Comstock Lode,—the great silver vein of the world. You are all of you, doubtless, familiar with the previous monographs of Messrs Hague and King and of Mr. John A. Church upon the same region. Since their time the workings upon this vein have been carried to a depth of 3000 feet, and rapid advances have been made in the science of lithology. In few mining regions is there found such a variety of eruptive rocks as in the Washoe mining district; such extreme and

* See page 428.

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universal alteration of their original constituents. It is not surprising, therefore, that Mr. Becker has arrived at many conclusions which differ essentially from those of his predecessors. What these conclusions are I do not feel at liberty to state, but they will be found embodied in his monograph, which is shortly to appear.

Mr. Arnold Hague has made a most exhaustive geological study of a district, twenty miles square, including the well-known silver mines of Eureka, in Nevada, which are only second in importance as producers to those of the Comstock Lode. Mr. Hague's work has been a most important one for the general geology of the Rocky Mountain region, as well as for the particular district to which it is confined. The study of the ore-deposits themselves is now being carried on by Mr. J. H. Curtis.

Mr. King's original plan contemplated the annual preparation of an ever-increasing number of such monographs as I have described of the more important mining districts of the country. It also contemplated the annual appropriation by Congress of at least half a million of dollars for the use of the Survey, certainly not an unreasonable amount in consideration of the immense and ever-increasing value of our mining industry. The actual money value of the work to the mining community can readily be appreciated by mining engineers, but Congress has not yet realized it, and may not for some time; hence, our progress, necessarily slow in the commencement, will be rendered more so by want of adequate funds, since with the present appropriations it is barely possible to keep up the present scale of work, much less increase its scope. Time will correct this, however, and in the meantime valuable assistance can be rendered by mining engineers, who furnish papers to the Institute, in giving definite geological information upon the metallic mines they are called upon to examine. The number of such papers, very small at first, has been steadily increasing with the growth of the Institute, but their numerical proportion is still far below what the importance of the subject demands.

While the geological branch of mining engineering occupies a prominent place in the work of the Survey, the more technical branches will by no means be neglected. The monograph on Leadville will be accompanied by an elaborate discussion of the processes of lead smelting, as conducted there, by an able analyst, Mr. A. Guyard, illustrated by working drawings of furnaces and all implements employed.

For the Comstock Mr. W. R. Eckart, the eminent mechanical en-

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gineer, is at work upon a report on its "Mechanical Appliances used in Mining and Milling;" also to be illustrated with complete drawings of machinery, and to contain a most valuable discussion of the effective result of different systems, founded on actual experiments and theoretical calculations.

Such papers, prepared by specialists best fitted for the particular work, should accompany every monograph, whenever there is any particular process or mechanical appliance in the district examined of sufficient importance to justify the labor and expense.

An annual review of the economical condition of mining industry, as deduced from accurate statistical information, is no doubt a legitimate and important branch of the work of the Survey, and in laying the foundation for this work we have been greatly assisted by the liberality of General Walker, the Superintendent of the Census. The collection of mineral statistics for the Tenth Census was placed by him under the management of the Director of the Survey, and facilities thus afforded for doing the work in a manner which the funds of the Survey would not have admitted of.

The valuable work of Dr. Raymond had been so long since discontinued that the field to be examined was statistically unknown, and it was determined to collect the desired information by means of actual visit of trained collectors to every mine, mill, or smelting work in the country, armed with the most exhaustive series of questions in regard to every phase of the work going on which our ingenuity could devise. We realized, in the commencement, that absolute or exhaustive accuracy could not be obtained, since for this would be required the very best mining engineers in the country as collectors, a universal willingness to give information on the part of owners, and more time and money than was at our disposal. Nevertheless, so far as it was possible, we attained that accuracy, and the result has been the accumulation of a vast amount of technical information, which is now being tabulated for discussion and generalization.

The results are necessarily unequal, as depending upon two varying factors, the relative intelligence and industry of collectors and the inherent difficulties of collecting, peculiar to each case or district. The deficiencies in our results are more noticeable in the statistics of production, which have already been published, since here absolute exhaustiveness is necessary, when in other branches, such as relative costs of labor, power, average consumption of steam, fuel, etc., imperfections in the returns from one or two mines in a district do

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not materially impair the correctness of the averages arrived at. Checks upon the synthetic system in the case of production were furnished by express and Mint statistics, and other sources, and additional amounts thus obtained could, in some cases, be distributed among the districts to which they belonged, but, in general, were simply added to totals from States. The labor involved in this work has been not only very great, but, on account of its inquisitorial nature, very annoying from the unwillingness shown, in many cases in a not over-polite way, to answer our questions. But I think the value of material obtained will amply repay the labor spent, especially if it is permitted to make the work permanent, so that the experience, gathered with so much weariness in carrying on the work thus far, may not be entirely lost.

Should the present Congress grant the appropriation we have asked for for this work, it will be conducted under a distinct head by a permanent set of employés, who will annually visit the region assigned to each and gradually systematize the work, so that production statistics may be published, it is hoped, within six months after the close of each fiscal year. This work will be materially accelerated by the experience already gained. We now know, as we did not fully know before, the locations of all mines, and the names of their owners or managers. A great deal of the work can be conducted by correspondence, and visits will be required only where important developments have been made since the last data were obtained, or new districts have been opened.

In the matter of collecting these statistics the influence of the individual members of the Institute can be of the greatest use to us, if they will take the trouble to explain to those mining men with whom they come in contact the practical value of the work, and persuade them to answer our questions promptly and in a friendly spirit. It is often more labor to get information from one or two reluctant individuals than from a whole district or State. If the work is conducted under these auspices, the assurance that all information obtained will be held as strictly confidential should be very great. The reputation of the Survey would be at stake in the first place, and all its members are forbidden by law from having any personal interest whatever in any mining property of any kind.

As supplements to the annual production-bulletin it is intended to publish a series of technical papers on processes and mechanical appliances in mining, milling, and smelting, for which the voluminous data already gathered will afford a most invaluable foundation.

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In conclusion, then, let me ask an indulgent judgment of our early work. It is a comparatively easy matter to plan, but few succeed in keeping their work completely up to the standard which they set for themselves. At the same time we by no means wish to avoid criticism. Honest criticism, that is free from malice, may be of the greatest assistance to the earnest worker, and there is no doubt that, were this kind of criticism more frequent, there would be less slovenly scientific work done in America.

THE MINERAL REGIONS OF SOUTHERN NEW MEXICO.

BY B. SILLIMAN, M.D., N.A.S., NEW HAVEN, CONN.

THE regions of New Mexico referred to are in Socorro, Grant, and Dona Ana counties, and a portion of Lincoln County, embracing in the aggregate a very large area, of most of which our knowledge is as yet very fragmentary and superficial. It is only very recently that large portions of this region have been accessible. It has been full of danger from hostile bands of wandering Apaches, whose murderous raids have slain many adventurous miners and seriously prevented developments. But this evil has now been largely abated, and in many of the mining camps of this region there is no longer any danger from this cause.

SOCORRO MINES.

About three and a half miles back of the old Mexican town of Socorro, on the Rio Grande, chief town of the county of Socorro, are two or more large veins of heavy spar, cutting across the face of Socorro Mountain in a northeast and southwest direction, and dipping at an angle of about forty degrees into the body of the mountain. These veins are in rhyolite, and, so far as could be seen in openings on the Torrence Mine, which I examined, are without any clay parting or selvage. The average thickness of the Torrence vein may be about five feet, the thickness varying from one or two feet to thirteen feet. Upon the cleavage planes of the heavy spar occurs, in visible patches, of a waxy lustre and gray color, silver chloride, which gives value to the vein, from a few ounces up to one hundred and twenty ounces to the ton, averaging about forty ounces, as I

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was informed. Associated with the heavy spar are several minerals carrying vanadium, one of which, in small yellow hexagonal prisms, is a mimetite containing vanadium, which has been mistaken for vanadinite. Farther research is required to determine the specific identity of the other associated minerals, which form no part of the economic value of these veins. The lowest explorations were, at the time of my visit (October, 1881), about two hundred feet on the slope of the vein, which was dry at that time. No stoping had then been done, and by measurement about three thousand tons of ore were in sight.

A ten-stamp mill, of excellent construction, stood on the edge of the Mesa, over the river, nearly ready for work, constructed under the direction of William M. Courtis, M.E., who has also developed the mine. The whole expense of the mill and its appointments, which were very complete, was stated at about $75,000, and the entire enterprise was a good example of legitimate mining.

There were no fossils found by which to determine the geological position of the Socorro Mountain, which is one of an extensive system of eruptive rocks, which I traced to the base of the Magdalena Mountains, about thirty miles west of the Rio Grande and the town of Socorro.

THE MAGDALENAS.

In a bold range of this name, about thirty miles west of Socorro, is a range of metamorphic slates and limestones, with gneissic—probably azoic—beds and quartzites, traversed also by porphyritic eruptions, where I found a strongly marked mineral lode, carrying huge masses of lead carbonate, of low grade in silver, averaging, probably, 25 per cent. of lead, and under ten ounces of silver. In a portion of this lode, known as the "Juniata," the ore-mass exposed was fully forty feet in thickness, at a point about sixty feet from the surface, and the total thickness of this great chamber was not less than sixty to sixty-five feet, as was shown by a drift driven in fully twenty feet beyond the workings in ore. At the end of this drift is a fluccan-like mass, two to two and a half feet thick, which appears to be the east wall. The containing-walls are fissile slates on the west, and a quartzose porphyry on the east. The vein is nearly vertical. Within the walls is a vast mass of decomposed material, impregnated with lead carbonates of every shade of color, from white to yellow-brown, with iron-stained and violet lithomarge. Probably one-half the whole mass is waste material. Mr. E. W. Eaton, of Socorro,

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who worked this mine, assured me it required four tons of the ore to produce one of bullion. One million pounds of this bullion, produced on the ground and sold in St. Louis, assayed twenty-three ounces of silver, or about six ounces per ton of ore, while the assay called for eight to ten ounces. Piñon charcoal was used in the smelting, and twenty-three bushels of coal, costing seventeen cents each, were consumed to the ton of ore smelted. Nineteen cubic feet of the ore was found to equal two tons, or nine cubic feet to the ton in place. As this ore body is likely soon to be brought into close connection by rail with the system of the Atchison, Topeka, and Santa Fe Railroad, and with cheap coke at Socorro, from coal mines lately opened on the east bank of the Rio Grande, near Socorro, it is likely to become an important factor in the metallurgical operations for which Socorro offers a convenient centre.

Other portions of this vein, which I saw about a mile and a half to the south, on the "Imperial" location, where it has been opened by a shaft sunk in the ore-body, about eighty feet deep, were heavily charged with zincblende. The total explored length of this vein is about two miles. Beautiful green and blue calamine are found among the surface ores along the "Kelly" location, north of the Juniata, and cryptocrystalline anglesite, inclosing galena, was observed at the same surface openings. While much of the ore on this gigantic mineral lode is of low grade, its position favors exploration by tunnel on the course of the vein at several points, with the probability of the discovery of other large ore-bodies like that noticed in the Juniata. It waits the advent of cheaper transportation and fuel.

Of the mineral region immediately west of the Magdalenas I saw only some hand samples of ores, chiefly of lead. But among them was an ore from the "Sophia," a small vein of heavy spar, carrying extremely rich copper-silver glance, corresponding closely to the species stromeyerite. But as I did not visit the locality I can say no more of it.

The magnetic variation of this district was, in October, 1881, 13° 45′ E., as given me by Mr. E. G. Shields, C.E.

The mountain ranges follow the general northeast and southwest course common to the region. South of Socorro, on the west side of the Rio Grande, are the Negretta or Black Range, the Mimbres, the Burros and Mogallones Mountains, of which something more remains to be said; while on the east side of the Rio Grande, in Lincoln County, are the Oscuras Mountains, probably of Permian age; the Organ Mountains, the Nogals, and the Sierra Blanco, or White

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Range of the Mescalaro Apache Reservation, and Fort Stanton, a portion of which I visited.

The Oscuras Permian Copper Beds.

In the Oscuras Mountains exist considerable deposits of copper glance, azurite, and malachite, carrying also a little silver and gold in a silicious conglomerate, forming parts of the conformable beds in a considerably extended area of Permian rocks. The copper ores are largely found about the organic remains of fossil wood and various small plants, transformed into copper casts of the original structure, frequently retaining traces of the carbonaceous material. The most important copper-bearing beds are capped by a strong quartzose or granitic conglomerate, above which are beds of sandstone and red marls; beneath are other conglomerates, clays, and dolomitic lime rock. I was unable, from want of time, to make any exploration of these interesting beds, so closely resembling those of Russia, where they have been so fruitful a source of copper for many years. But I succeeded in securing the services of Dr. M. G. R. Fitzgaertner, at that time in Santa Fe, to go down there in the interest of the owners. Dr. Fitzgaertner's report is before me, and from his statements it appears these copper-bearing beds carry from 10 or 12 per cent. to 60 per cent. of copper, with a little gold (one-fourth ounce to one and a half ounces) and a few ounces of silver. The copper seams vary from a few inches to two or three feet in thickness, and they have a dip to the south from near the horizontal to 45°, the copper-bearing seams being a series of four, of which the strongest is immediately beneath the granitic conglomerate. These beds are about fifty miles below Socorro, near the wagon road to White Oak Mines, to the south, from which they are distant about forty miles. Good coal exists near the Oscuras, on the east bank of the Rio Grande, and has been developed by the Atchison, Topeka, and Santa Fe Company with a branch road and coke ovens, as I am informed by one of the officers of that road. Water is very scarce at surface.

I made also a careful examination of a much-cited deposit of vitreous copper, near Fort Stanton, in the Mescalaro Apache country. The ore of this locality is as fine as possible, but it exists only in trifling quantity, and with no evidence of continuity. There is no vein, and it does not occur even in a bed. So there was no reward for a toilsome journey over a desolate region, but to counsel the total abandonment of further exploration.

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Very different was the result of observations made in Dona Ana County, on the west side of the Rio Grande, the next region of my observation. This requires a much more extended notice.

The Lake Valley, or Sierra, Mines.

The Lake Valley mines are in the county of Dona Ana, New Mexico, near the point where Grant and Socorro corner upon it, lines established by a recent decision of the Territorial legislature.

LAKE VALLEY.

Lake Valley is a name appropriately given to a secluded valley, surrounded by the foot-hills of the Mimbres or Negretta Mountains, in the upper angle of which is a small lake, hidden from view by aquatic plants, and vocal with waterfowl. This lake evidently once covered a considerable portion of the adjacent valley, the level surface of which everywhere yields water by shallow wells. The water for the mill is supplied from the lake, or from a well fed by its waters.

APPROACH AND POSITION.

The approach to the Lake Valley mines is by the Atchison, Topeka, and Santa Fe Railroad from Nutt Station, which is 1105 miles from Kansas City, about 450 miles from Pueblo, 266 miles south of Sante Fe, and 104 miles from the old Spanish city of Socorro, now fast becoming the point of important mining industry, since the above railroad has supplied and is supplying transportation for the ores of silver, lead, copper, etc., and also for the coal of the near neighborhood. From Nutt to Lake Valley is a pleasant drive of about twelve miles, over an open country, by as fine a natural road as exists anywhere, with gentle ascending grade, and at a pace which easily places the traveller there in two hours from the railroad to the mining camp, which is, by aneroid, about 5700 feet above tide.

No mining region in this country is more agreeably situated, or more easily approached, than that of Lake Valley. Here no winter snows or severe cold interfere with travel, or with continuous and profitable labor. It is, essentially, a dry region, but already water has been reached in mining, and the water from the lake has also been brought in by a line of iron pipe.

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SURFACE APPEARANCES.

Entering Lake Valley by the road from Nutt Station, nothing is visible of human occupation, until a sudden turn to the right opens through a sag in the hill a view of a broad surface, dotted over with what appear to be piles of iron ore, scattered over a considerable area.

The extent of mining ground, covered by the united claims of the *Sierra Plata*, *Sierra Grande*, *Sierra Bella*, and *Sierra Apache* mining companies, is a compact body of about 350 acres, over the whole of which exploration has been rewarded at numerous points by the discovery of silver ore in greater or less abundance. This area is nearly a mile long on the diagonal from north to south, and about half a mile in the opposite direction. It is bounded by the edges of a valley of erosion on the east and west, by a hill of rhyolite or propylite on the south, rising rather sharply from the point of greatest depression in the *Grande* and *Plata* claims, while to the north the descent is rather abrupt from the borders of the *Apache* company's locations to the level of Lake Valley beyond. Within this area there is considerable diversity of surface.

The lowest and most level part of the property is where the more important developments of rich ore had been made, when I saw the property in October, 1881. This was true, especially on the *Stanton* and *Lincoln* claims, portions of the *Plata* and *Grande* grounds.

To the north and west of these claims, the ground rises rather rapidly, and upon the upper edges of the *Columbia*, *Strieby*, etc., reaches an elevation of probably 250 to 300 feet. From this western ridge the ground falls to the east, where a shallow, longitudinal valley divides the property into two pretty nearly equal portions, as may be seen by a glance at the map and plans of the several claims.

Early in the history of this property, considerable work was done upon the *Columbia* and *Strieby* claims of the *Sierra Bella*, and the *Kohinoor* and *Crescent* claims of the *Sierra Apache*. Indeed, it was from the *Columbia* shaft that the first surprising masses of solid chloride of silver were taken, that were cut out by a hand-saw. A shipment of ore from the *Columbia* shaft, made by former owners, gave returns from over fifty tons of ore, of about 500 ounces per ton, and of this lot 5 tons carried 3600 ounces of silver to the ton. This information I obtained from the former owners.

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THE GEOLOGICAL HORIZON.

The geological horizon of the *Sierra* mines is at the base of the Carboniferous. The fossils, which I collected there, have been examined by Mr. Arnold Hague, of the United States Geological Survey, and formerly of the 40th Parallel Survey. He says: "Your collection of fossils interested me very much, and proves to be an important one from a geological standpoint, as they are a horizon at the base of the Carboniferous, and not far above the Devonian, although, as yet, no Devonian fossils have been found immediately below them. . . . This grouping of fossils bears a very close resemblance to several made in the Wahsatch and the ranges of Utah from the Wahsatch limestone. Below this group, which is regarded as corresponding to the Waverly, nothing which is characteristic has been found. . . . So far as I know, this grouping has never before been recognized east of the Wahsatch Range." . . .

The basement rock, laid bare by the erosion of the upper beds, at Lake Valley, is a heavy-bedded gray or blue non-fossiliferous limestone, in and beneath which the silver ores are found. Above it are piled thin-bedded, shaly limerocks, full of fossils, and bearing no metallic ores, so far as known.* These upper fossiliferous beds have been extensively worn away by erosion, especially over the southern portion of the area, covered by the claims of the *Sierra Grande* and *Sierra Plata* companies, exposing the heavy basement limerocks, which here show frequent seams and cracks, filled with a dark brown—almost black—mineral, breaking with a bright-red streak

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* NOTE, July, 1882.—It was these beds which furnished all the fossils seen by Mr. Hague. Professor Cope subsequently made another search, and found some new species of zoophytes and crinoids, but nothing which changes the geological horizon, as indicated in the text.

NOTE, November, 1882.—Professor Cope, on authority of Dr. C. A. White, first referred the Lake Valley fossils which he had received from the late George Daly, to the Middle Carboniferous (American Naturalist, August, 1881), and later confirmed this reference after collecting on the ground. (American Naturalist, October, 1881.) Mr. S. A. Miller, in December, 1881, gives a description of these fossils, and locates them in the Carboniferous.

Mr. Hague and Mr. Walcott, who is an authority in palæontology, in January, 1882, referred my collection, which I had put into Mr. Hague's hands for the purpose of determination, to the Lower Carboniferous. I had supposed they might be Devonian, but my opinion on palæontology was not entitled to much weight. This statement of Professor Cope's earlier recognition of the Lake Valley fossils as Carboniferous, is due to him on the score of priority. See correspondence in Engineering and Mining Journal, October 21, 1882, p. 214.—B. S.

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or powder. The gravel and boulders, resulting from the breaking-up of the upper measures, have lodged over, and covered portions of the lower rocks. These loose materials have been penetrated by some of the shafts, before reaching the metalliferous zone. This red ore is hematite iron ore (specular iron), carrying here almost always more or less silver as chloride. These dark seams somewhat resemble pitch, or asphaltum, and nothing could be more deceptive, or less promising of value for silver. No wonder it was long overlooked.

DIP OF THE STRATA.

The dip of the beds of this group of rocks is to the east. The angle of dip is clearly seen, both in the Columbia shaft, and more recently, on a considerably more extensive scale, in the Strieby shaft, where it falls gradually from about 30° near surface, until at the depth of about 180 feet, where water has temporarily arrested exploration, it is quite flat, not more than 10° or 12°. The silver-bearing vein has for its cover or hanging wall this regular bed of lime with a smooth clay-like parting so far as followed. The significance of the fossiliferous beds here described will be readily appreciated, and the important key they afford in future exploration has a forcible illustration in the exploration of the deep shaft on the "Hopeful," of which more detailed mention is made in the postscript to this article.

MINERALOGICAL CHARACTER OF THE LAKE VALLEY ORES.

It will be understood, from what has already been said, that the chief ores at these mines are silver chlorides and silver-lead carbonates, associated with specular or red hematite iron ore, and a certain amount of galena and manganese ores. The silicious ores carry embolite, and some of them are rich in silver chloride and lead carbonates, with small quantities of vanadinite, and native silver. Gold is absent, unless in the most insignificant traces. Sulphurets are almost completely absent, galena being nearly the only exception.* This lead ore is frequently seen in small particles among the lead carbonates, and, occasionally, masses of many pounds weight are found, which have escaped the general decomposition which has converted

* The exception here alluded to is the pyrite found in the rhyolite or propylite as seen in the deeper explorations.

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this species into carbonate of lead.* The assay of a fine granular mass of this galena, nearly pure, showed 117.88 ounces of silver.

ENUMERATION OF SPECIES.

The enumeration of the species of minerals, at present found at Lake Valley, includes the following, viz.:

METALS. (1), *Silver*,

a, metallic silver (in trifling quantity).
b, chloride of silver, horn silver, or kerargyrite.
c, embolite, chloro-bromide of silver.
d, silver-bearing lead, both carbonate and sulphides.

(2), *Lead*,

a, galena, and carbonate of lead, both rich in silver.
b, vanadinite, or vanadate of lead, of a light yellowish color, in minute hexagonal prisms, and without arsenic.

(3), *Iron*,

Specular, or red hematite, and brown iron ore; the former most abundant and the chief gangue or associate of the silver chlorides. Both are highly valuable as fluxes in smelting the ores.

(4), *Manganese*,

Pyrolusite, manganite, wad, or psilomelane.

NON-METALLIC MINERALS.

(1), *Quartz*,

As the gangue of embolite, and in places the cap-rock of the ore-body; varieties, flint and chert. Also, in small quantity, drusy crystals of quartz, with vanadinite.

(2), *Carbonate of Lime*,

Chiefly as gray limestone, being the heavy-bedded capping to the ore-body, but found also coating silver chlorides in the masses of ore, and, likewise, as crystallized calcite.

* It is not easy to say what has become of the sulphuric acid, equivalent to the sulphur of the lead sulphides (now carbonates). No anglesite exists, and no gypsum, as might most reasonably be expected.

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(3), *Ankerite*,

Or lime, iron, manganese carbonate.

(4), *Apatite*,

Or phosphate of lime (rare).

Exploration will probably bring to light other species, but I saw no others in my inspection of the mines. The result is surprising from its simplicity, and the absence of offensive smelting minerals, like zinc, arsenic, antimony, etc.*

CROPPINGS OF CHERTY QUARTZ, AND IRON AND MANGANESE OXIDES.

A capping of compact flinty quartz takes the place of the above-mentioned heavy-bedded limerock, covering the silver-bearing iron ore in the same manner as does the limerock. This silicious capping might very properly be called "vein stone," as it carries a valuable quantity of silver in the form of embolite, or chlorobromide of silver, the greenish color (yellowish green) of this ore being quite evident to the mineralogical eye. It is a milling ore, often quite rich in silver. The seams of iron ore in the limestone, as above described, often lead into large bodies of rich silver ore, when followed by mining explorations, over which the heavy-bedded limerocks form a capping. These ore-bodies vary very much in extent, depth, and thickness. The largest body of this kind, explored at the time of my visit, was that reached by what was known as the "Joint Shaft," between the *Plata* and *Grande* companies' ground, on the line between the *Stanton* and *Lincoln* claims.

The character of these very rich ores is absence of any silicious gangue, the whole mass being a loosely aggregated congeries of crystals of silver chloride (horn silver) with carbonate of lead, the whole mass stained deeply throughout with red iron oxides (hematite), and more rarely black with manganese oxides. It is a splendid smelting ore, but far too rich for milling. Only the lower grades of cherty and ferruginous ores, under 100 ounces to the ton, will be proper material for the mill.

* Although no antimonial compounds were detected among the Lake Valley minerals, some form of antimony exists in minute quantity, since the silver bars uniformly contain a minute trace of this metal, derived probably from the oxidized ores in amalgamation.

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Assays of the Ores.

Cherty Croppings.

I cite the following assays made at the mines, October 18th, 1881, on cherty samples taken by me from the west drift of west cut near the surface:

Chert with embolite, silver per ton, 240 ounces.
Flint with embolite, silver per ton, 186 ounces

Other samples of silicious croppings from the same cuts, with native silver, lead carbonates, and embolite, gave me respectively 490 ounces, 1460 ounces, and 164 ounces of silver to the ton.

Iron ore, with embolite, taken 500 feet from northeast corner of *Stanton* claim of *Sierra Plata* at surface, gave me 400 ounces silver to the ton.

Every sort of mineral in those croppings gave silver on assay. A mass of brilliant crystals of pyrolusite (manganese ore), gave me 45 ounces of silver per ton, and pieces of croppings, "believed barren," gave from 9 ounces upward.

Ores Rich in Lead and Silver.

1. A sample sack, taken from the dump of ore extracted from shafts 3 and 4, being a very ferruginous ore mixed with carbonate of lead, yielded, lead 32.4 per cent., and silver 129.42 ounces per ton.

2. A sample sack taken from the bottom of the south drift west shaft, gave, lead 19.2 per cent., and silver 281.33 ounces per ton; this was somewhat silicious.

3. Carbonate ore, selected dump, slightly silicious, from east drift, gave 28 per cent. of lead, 415.62 ounces of silver.

4. A sample sack of rich chloride and ferruginous ore, with manganese, taken from face of the east drift of the "Joint Shaft" of *Plata* and *Grande*, gave, lead 20 per cent., silver 10,289.69 ounces.

In all these samples, the lead is sufficient in quantity to bring the ores within the smelting classification of lead ores, the lead being almost entirely as carbonate, derived, beyond doubt, from the transformation of galena.

Working Tests.

Messrs. Mathey and Riotte, of the New York Metallurgical Works, have kindly supplied me with the results of milling some lots of the *Sierra* mines ores, forwarded to them from the mines at the time of my visit. These tests were made by free milling amalgamation,

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both with and without the use of chemicals. These results are as follows, viz.:

	Per cent.
Ore from *Sierra Grande*, without chemicals, yielded . . .	79
Ore from *Sierra Grande*, with chemicals, yielded . . .	76
Ore from *Sierra Plata*, without chemicals, yielded . . .	54
Ore from *Sierra Plata*, with chemicals, yielded	75
Ore from *Sierra Bella*,* without chemicals, yielded . . .	57
Ore from *Sierra Bella*, with chemicals, yielded	68½

Of the Treatment of the Ores from the Sierra Mines.

These ores may in one sense all be properly called free milling ores, but practically they divide themselves into two groups, viz.:

1. Smelting ores.
2. Milling ores.

To the first group belong all the rich silver lead ores, carrying 20 to 30 per cent. of lead as carbonates, and from 100 ounces of silver to 10,000 ounces, and even more than this. Lead is all lost in milling, but in the smelting ores it is paid for by smelters, if present up to the limit of 20 per cent. The combination of ores in the *Sierra* mines makes the best smelting mixture possible for rapid and economical work, without loss—no zinc, copper or arsenic, antimony only in feeble traces, and little silica, while iron, manganese, and lime, act as fluxes.

The best milling results possible on these ores involve a loss of from 25 to 40 per cent. in silver value, while the smelter pays for the entire silver value, less three ounces; and the schedule price of $20 per ton for smelting, forms a small item in the returns, on ores of many hundred ounces of silver value. The few milling tests above cited sustain this statement as far as they go. Even on ores of 100 ounces value, smelter's charges, less freight, are less than the milling losses. Experience at Silver Cliff and elsewhere has shown that manganiferous ores which carry silver, pass through the mill without amalgamating, and the silver value is found in the tailings.

The milling ores of the second class will, therefore, in this case, embrace, properly speaking, only the silicious ores, and some of the ferruginous ores carrying chloride and chlorobromide of silver. The

* From the *Columbia* claim, very ferruginous ores, full of chloride of silver and no lead.

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cherty ores particularly, are unsuited for smelting, and must be treated in mills, except where they contain, as some of them do, silver to the extent of several hundred ounces.

Smelting Facilities.

For immediate use, the Pueblo Smelting Works of Messrs. Mather & Geist, the works of the Boston and Colorado Smelting Company, at Argo, near Denver, and the works at Omaha and Leadville, offer every facility, with the advantage of competing rates. For the future it is quite possible that smelting works on a considerable scale may be erected at Socorro, where many circumstances appear to point to a prosperous development in the smelter's art.

Of the Nature and Probable Origin of the Lake Valley Silver Ores.

From what has gone before, it will be understood that the Lake Valley mines belong in the same category with the Leadville, and probably the Eureka and other deposits in the older limestone formations, and that they are not fissure veins. That these deposits may equal in value and permanence any other form of silver deposit, cannot be denied, in view of mining experience of a like nature the world over. The opinion is well-nigh universal in favor of a fissure vein for permanence, but the history of mining adventures is full of examples of the fact, alas! so common, that while the vein remains, the character of Hamlet has been left out of the play! What proportion, for example, of all the vast area in extent and in depth, which the last twenty odd years have opened upon the Comstock, has proved ore-bearing? The bonanzas, as seen in a projection of that famous fissure, have been the rare exception.

At Lake Valley the ores are of exceptionally high tenure in silver, and, compared with Leadville, Eureka, and Little Cottonwood, are low in lead.

In the simplicity of their mineralogy and metallurgy, the Lake Valley ores, as already remarked, are also exceptional. It remains to be seen if, on deeper exploration, these conditions remain unchanged.

The absence of hydrated species is remarkable. The iron exists chiefly as specular iron, and the same is true of the manganese. This fact indicates the probable existence of a temperature adequate to prevent the existence of limonite or hydrous peroxide of iron. This temperature might be supplied by superheated vapor of water, escaping with other heated gases, from the deep. The chief interest

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of such a speculation in this case is the probability implied, that we may look deeper for ore without touching bottom.

The origin of the silver is probably connected with the bodies of trachytic rock, propylite, rhyolite, etc., which exist as eruptive masses and dykes in this region. As yet the explorations have only partially developed the extent and position of these eruptive rocks. It is probably from them that the silver has been derived. And the same chemical agency which has dissolved the silver from its former condition in these has set free the silica, now found in the cherty croppings, and the iron and manganese ores associated with them.

These cherty croppings are particularly strongly developed. On the high ground of the Apache, some 500 feet above the rich ores of the Plata and Grande, or of the Sierra Bella, associated with the Apache croppings, manganite occurs abundantly, and some very rich silver chlorides. But as yet almost nothing has been done toward the development of this most considerable body of elevated mineral ground.

Postscript, July, 1882.

The writer made a second visit to the Sierra Mines in June last, and found some important changes in the interval since his former visit, viz.:

The Mill.

A very complete and well-constructed silver mill, of 20 stamps, with space and power for 40, has been constructed, and was put in successful operation during the month of June. It is provided with the new system of continuous discharge, devised by Mr. Boss, of San Francisco, designed to save the labor of handling the pulp from the tanks to the amalgamating pans. This system is said to have worked well in other cases where it has been tried, and it certainly has the merit of simplicity and economy.

The water for the supply of this mill, is laid on by a line of wrought-iron pipe from the pump station near the lake, about three miles distant.

For the actual output of this mill, and the loss of silver in the tailings, we must wait the results of experience.

New Developments on the Bella, and on the Plata and Grande Ground.

Our present concern is chiefly with the developments on the ore-bodies by explorations in depth. Of these, there are two or three

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which are of special interest, from the light they shed upon the whole district.

(1.) On the "Bella," the claim called the "Strieby" has been opened by a shaft sunk on the dip of the ore-body, which has at this point an angle of about 30° S. E. The hanging wall has a smooth and continuous contact surface, with a clay parting above the ore-body, which has a thickness of about five feet of mixed carbonates of lead, with silver chloride stained deep-brown by iron-manganese oxides; the average assay value of which has been over 100 ounces per ton. The dip of this ore-body has gradually flattened, until at about 180 feet on the slope, where water has for the present arrested further progress in sinking, its inclination is not more than 12° or 15°. The underlying, or foot-wall, of limestone, of this ore-channel is less well defined than the upper wall. It exposes near the bottom and in the drifts a compact rhyolite, well sprinkled with minute crystals of pyrite. The important relation of these intruded porphyritic masses to the silver deposits has already been mentioned, and need not be elaborated here.

This important exploration has exposed a body of ores variously estimated at from 12,000 to 15,000 tons, and has indicated the position for a downright shaft, which is to be sunk immediately, for the further prosecution of the work, the unwatering of the ore ground, and the economical hoisting of the ore to the surface.

Ninety-eight assays in April, May, and June, 1882, taken from the daily workings in sinking the Strieby shaft and drifting, gave an average of 110½ ounces of silver per ton.

(2.) Another similar exploration has been commenced near the southwestern limit of the Plata and Grande ground. Here a cross-cut passes through about twenty-five feet of ore, black with manganese and iron, but well charged with silver chlorides, and cutting the underlying limerock. A shaft, sunk downright in this black ore mass, at the depth of about 30 feet, struck the same underlying limerock, and is now sinking at an angle of about 70° in the ore-body. The strike of this ore-body is the same as that in the Bella (S. E. or N. W.), but from its position being too far to the west of the Strieby shaft, it can hardly be the same ore-body, and it is yet too soon to say with certainty that it will repeat the experience of the Strieby, but such is its present appearance. New masses of extremely rich chloride of silver have also been developed by recent explorations on the Lincoln and Stanton claims, and it is said in large quantity.

From these explorations it appears, so far as now seen, that there

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are probably three distinct zones of ore-bearing ground, viz., those on the Plata and Grande, that already described as seen in the Strieby shaft, and, lastly, that laid open by the so-called Columbia shaft, which is in advance of the Strieby, to the southeast, and where the first rich ores were extracted by the former owners. The value and necessity of continued exploration are thus clearly shown. And this obvious truth has lately received a most important confirmation, as the result of a well-directed and intelligent work, which was already in progress last autumn, but which has only very recently come to a successful issue. I allude to the work undertaken by other parties, beyond the limits of ownership of the "Sierra" companies, upon ground, known as the "Hopeful," viz.:

The Hopeful Shaft.

Rising easterly over the dividing ridge of the valley, in which are found the basset edges of the fossiliferous beds already described, we find the "Hopeful" location, distant about 2000 to 2500 feet from the Strieby shaft, with a gentle surface slope to the southeast, near the southwest angle of this location. Mr. H. H. Sawyer and his associates commenced last autumn a downright shaft, expecting to cut the ore-body of the Columbia in depth. It was a bold undertaking, considering how little was then known of the nature and extent of the Lake Valley ore-deposits, and naturally was regarded with much incredulity by all to whom the general structure of the region was an enigma. The result, so far, has well vindicated the intelligence which inspired the undertaking. After sinking for more than one hundred feet through barren non-fossiliferous limestone beds, the beds of the Lower Carboniferous shaly limestones, full of the same fossils, already mentioned as overlying the ore-bodies, were cut and passed through; next followed the heavy-bedded limestone, overlying the "iron cap," which marks the horizon of the ore. At the depth of 155 feet a strong flow of water arrested sinking, until a pump and hoisting apparatus can be put in place. This shaft passed through three feet of this ferruginous capping, from which, as I am informed by Mr. Sawyer, assays of 2 to 20 ounces of silver are obtained. This very interesting result appears definitely to settle the question of continuity in extent and depth of the Lake Valley ore-bodies, at least for that portion of the area thus explored. It remains now to be determined by further prosecution of the same exploration: 1st. If the "iron cap" here cut covers a similar ore-mass to those already found near surface on the Plata and Grande and Bella; 2d. If the indica-

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tions of a succession of like ore-masses overlying each other is verified, such as now appear to exist near surface as three distinct zones. The interest and importance of the solution of this question are self-evident. But as it now stands, the result already attained cannot fail to stimulate similar explorations, both within the "Sierra Mines" areas, and upon the "Outside Claims." Already a large area of surface is covered, especially to the southeast, by such mining locations, upon which at this time no work has been done.

So far as exploration has gone no faults nor dislocations have been discovered in the Lake Valley region, but it can hardly be expected that such disturbances will not be encountered, probably not to the same extent as at Leadville, since the whole area surrounding Lake Valley is formed from the lower foot-hills of the Mimbres and Black Ranges, and has not felt the stress of a great upheaval of central mountain masses, which have thrown the strata at Leadville into such complicated foldings and faultings, with an elevation of over 10,000 feet. Compared to the Leadville region, Lake Valley is an area remarkably free from such disturbances.

As Lake Valley, especially the areas of the Sierra Mines, is at surface a dry region, quite devoid of surface water, it is an interesting fact that an ample flow of water should be found at so moderate a depth as that now reached (155 feet) in the Hopeful shaft, where 180 buckets per hour did little to lower the level of the water in the shaft. The value of such a water supply in a dry region is considerable, but its significance as an evidence of extended areas of drainage, and inferentially of ore-ground also, is of more importance yet.

It remains yet to speak, very briefly, of some other regions of Southern New Mexico, and especially of the Negretta or Black Range.

The Black Range.

This mountain range is on the west side of the Rio Grande, about fifty miles from that stream, and it extends southwardly from a point nearly opposite Socorro across Socorro County, and into the adjoining county of Grant, at least one hundred miles. No good map of this portion of New Mexico exists, and the Negretta or Black Range (so called because of the dark-colored firs which cover it) is often confounded with the Mimbres Mountains. We approached this range from Engle, a station on the Atchison, Topeka, and Santa Fe Railroad, fording the Rio Grande near old Fort McRea, and thence crossed the subordinate Cuchillo Negro Range, about half way to Grafton, a mining settlement on the eastern flank of the Black

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Range, about 9000 feet above tide. The whole of this region was considered so unsafe, both from hostile Indians and worse white banditti (called "*Rustlers*"), that it was thought necessary to provide a military escort, which, together with the guns carried by the party, gave us twenty-five Winchesters and two mounted scouts perfectly familiar with the country. No difficulty occurred, however, nor was any likely to happen to so strong a party.

The Black Range is intersected by powerful lodes carrying gold, silver, copper, zinc, and lead. Hagan's Peak, a prominent landmark, which forms the apex of the range, appears to be a centre from which radiate numerous veins. One of these, known as Hagan's Lode, is covered for over two miles by successive locations, the ores of which are chiefly valuable for silver, with a little gold and some yellow copper, in a coarse-grained crystalline and cellular quartz, the vein being generally very large, *e. g.*, "The Midnight" samples gave me silver 15, 43, and 118 ounces, from three portions of the vein, a trace of gold, and under 5 per cent. of copper. "The Colossal" had 127 ounces of silver, ½ an ounce of gold, and about 7 per cent. of copper. The "Monte Christo" yielded, silver 168 ounces, gold 1 ounce, with under 1 per cent. of copper. These are obviously all free milling ores, the silver existing chiefly as chloride; galena and lead salts are rare.

This vein is believed to extend to the north much farther than above indicated, covering in all a stretch of many miles. But no competent observer testifies to the truth of this statement as the result of personal investigation. All I can say is, that I saw a powerful vein, which I followed for more than two miles from the town of Grafton, commencing at the "Ivanhoe," and passing the Buckeye, Surprise, Alaska, Montezuma, etc., and so on, to the north, and beyond, where I followed it to the "Wild Horse." It is said to maintain its course conspicuously for about five miles from the point of starting.* At the "Montezuma" it was over 20 feet wide; a mass of hard quartz, with noble combs of amethystine crystals and great subveins of calcite included, with streaks of ore. It was developed by a shaft, sunk in the eastern porphyry, which incloses it, and the vein remained almost undisturbed for 150 feet, the depth of the incline shaft, at that time. Samples which I collected gave about 1 ounce of gold and 140 ounces of silver.

This vein is certainly worthy of a systematic development. The

* If the vein from Hagan's Peak to the "Wild Horse" location is one vein, its length is from ten to twelve miles.

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gold is not visible to the eye, and the silver exists chiefly, if not entirely, as chloride.

The Ivanhoe mine is that which has given to the Black Range its chief fame. It is opened on the same vein, and, so far as it has been explored, the work was done by Colonel Gillette with good judgment and economy. At the time I saw it a tunnel had been run in along the course of the lode, about 100 feet below the croppings, for a distance of between 200 and 300 feet, and a shaft sunk to the next level, 100 feet; also a winze 100 feet beyond to the same level. The vein was of remarkable interest, and at the time of my visit of exceptional value. There was a streak of black ore a few inches wide on the footwall, about the level of the tunnel, which was brilliant with free gold, implanted in a matrix of blackened carbonate of lead, owing its color perhaps to the effect of light upon the silver chloride it contained. The mineralogical character of this black zone was rather complex; vitreous and variegated copper, blue and green malachite, yellow copper, zinc blende, calcite, cerussite, free silver, silver chloride, and gold, exist in its quartzose gangue. Carefully prepared samples of this rich ore gave from 50 to 60 ounces of gold and 250 ounces and over of silver. This naturally gave an unwonted stimulus to speculation, which the development of the vein in depth did not sustain. But it is nevertheless a remarkable vein, as its average quartz is good for from 1 to 2 ounces of gold, and from 100 to 150 ounces of silver. The vein is strong, varying from 3 or 4 feet to 10 feet in thickness. Portions of it which I broke at 200 feet depth on the hanging-wall side were beautifully brecciated like a mosaic, showing evidently former mechanical violence, the cementing silica which bound the fragments being chalcedonic, bordered with fringes of metallic particles symmetrically arranged like lines in an agate.

Much more might be said, respecting the Ivanhoe and the Great Master lode, on which it is opened, but it is enough to add, from what we know of it, that systematic exploration, in depth, alone will develop its hidden treasures, and not the manipulation of its shares in Eastern cities. The cross valleys or gulches, which cut this great vein, offer numerous points, where it may be advantageously opened by tunnels driven in on its course.

Timber abounds on the Black Range, and water exists in quantity sufficient for milling purposes. It is a region full of wild game, and was the chosen resort of Victorio, who declared that no white man should set his foot on the Negretta and live; an oath which

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he kept as long as he lived. Near Grafton is an old burial-ground of the Indian race to which Victorio belonged.

It is easy to say much more of the Negretta and the Mimbres, of the Burros and the Mogallones, but most of the information I possess of those regions is derived from other observers, and I propose here to restrict myself to my own explorations, leaving to others the development of the regions beyond.

Pyromorphite replaced by Wulfenite and Vanadium Compounds.

Many years since I first called attention to the fact, before unrecorded, that pyromorphite, so characteristic a mineral in the lead-bearing veins of the Appalachians, and of Great Britain and the European continent generally, was almost completely, if not entirely, wanting in the lead and silver-bearing veins and beds of the Cordilleras of Central North America. In them phosphoric acid is replaced chiefly by molybdic acid, and not unfrequently, as I have since discovered, by vanadic acid, the former appearing as wulfenite often, as at Tacoma and Eureka, crystallized in specimens of unsurpassed magnificence, and *passim* in less conspicuous forms; the latter I have more recently detected in a considerable number of localities in Arizona and New Mexico, as is more particularly set forth in a paper, in the *American Journal of Science*, for August, 1881. At Lake Valley, vanadinite occurs in small but very perfect hexagons, of a yellow color, closely resembling some habits of pyromorphite or mimetite. It is not common, but I found a considerable mass of drusy quartz on the Lincoln claim, quite abundantly studded with these crystals, about a millimeter in diameter. Wulfenite has not so far been detected at Lake Valley.

The veins of the Negretta, or Black Range, mentioned in this paper, are quite barren of wulfenite and vanadinite, so far as observed at present. On samples from the "Tidal Wave," a location on the Hagan lode, I detected a few crystals of pyromorphite, the first I have seen beyond the Wahsatch, where, in 1872, I first distinguished the replacement of that species by wulfenite. But it is to be remarked that the veins of the Black Range are essentially non-plumbiferous; they are silver-bearing gold veins, with a little copper, and less lead, so far as I have seen them.

At Socorro, as already mentioned, occur vanadium minerals, one of which is a *vanadiferous mimetite*, a variety of this arsenide, not, I believe, before noticed. There are two other vanadium minerals

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there, one of which is, very probably, descloizite, but they remain to be studied with more care than I have yet been able to devote to them.

A REVIEW OF THE STE. GENEVIEVE COPPER DEPOSIT.

BY FRANK NICHOLSON, E.M., STE. GENEVIEVE, MO.

HISTORICAL SKETCH.

COPPER ore was first noticed in Ste. Genevieve County in 1863. The discovery was made by a German farmer named Simon Grass, who had occasion to make a road from his farm down the hill into the neighboring valley, and while so engaged noticed pieces of a green-colored mineral, some of which he collected. Not knowing the character of the ore he had found, and supposing it to be valuable for its brilliant green color only, he carried a piece with him into the town of Ste. Genevieve and showed it around the various bar-rooms as a curiosity. No special attention was paid to the matter until nine years later, when Mr. O. D. Harris sent a specimen of the ore to Dr. Theodore Fay, of St. Louis, for analysis. This analysis, which was the first ever made of Ste. Genevieve copper ore, showed the specimen to contain :

Copper,	17.75 per cent.
Zinc,	3.21 "
Iron,	24.50 "
Sulphur,	1.09 "
Organic matter, silica, carbon, and oxygen,	53.45 "
	100.00 "

From this analysis it is evident that the sample was taken from near the surface, and was probably recognized by its green color. The almost entire absence of sulphur proves it to be an oxidized form.

There is on file, at the office of the Ste. Genevieve Copper Works, a paper* giving three assays of the ore made in 1875 by Henry B.

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* The paper referred to reads :

"Résultat d'analyses quantitatives de trois principaux minerais de cuivre de la nouvelle veine dans la montagne Dudley, Harris, et Cie.

1. Cuivre pyriteux, variété lamelleuse, avec des couches minces d'ocre ferrugineuse; cuivre métallique, 33.5 per cent.

2. Cuivre oxidulé ferrifère, var. compacte ; cuivre met., 36 per cent.

3. Cuivre oxidulé ferrifère, var. granuleuse ; cuivre met., 35.1 per cent.

Pour analyse,

STE. GENEVIEVE, MO., Mai le 9, 1875. HENRY B. YELITRE."

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Yelitre, a French chemist. These assays show very high results. They are as follows:

No. 1, Copper pyrites, lamellar variety; metallic copper, . .	33.5 per cent.
No. 2, Oxidized copper and iron; metallic copper, ...	36.0 "
No. 3, Oxidized copper and iron; metallic copper, ...	35.1 "

The result shown in No. 1 is higher than I have ever been able to obtain from chalcopyrite from this county; Nos. 2 and 3 are probably impure tenorite. In 1868 explorations under the direction of Mr. Harris were begun on the section where the croppings had been noticed; but after a short period of unsuccessful prospecting the work was abandoned. In 1872, four years previous to the death of Simon Grass, Messrs. Harris, Rozier, & Co. obtained a lease on the property for twenty-five years, paying 10 per cent. royalty. In 1876 work was begun on the hill opposite that on which copper was first discovered, by a Chicago firm styled Hitchcock, Wilson, & Co. After one year's unprofitable working this firm failed. The Chicago mine —this was the name applied to the old workings of the Chicago Company—was bought in by O. D. Harris, who now owns both the Grass and Chicago mines and operates them under the name of the Cornwall Copper Mines. In 1876 Mr. Leon Jokerst discovered another outcropping of copper ore, about four miles north of the Cornwall mines, and took out considerable ore, running from 20 per cent. to 27 per cent. of metallic copper. Following the lead taken by Mr. Harris, Mr. Jokerst called his property the Swansea Copper Mine.

In 1879 a third property was opened near the Swansea mine, and was named the Herzog Copper Mine. These three mines are those given in the Census Reports, by Professor Pumpelly, and a study of them will be a study of the Ste. Genevieve copper deposit. They all belong to the same formation, and a study of one reveals the characteristics of all. As the Cornwall mines are most largely developed, having, in fact, furnished nine-tenths of all the ore produced by Ste. Genevieve County, and, further, as the Swansea and Herzog mines are at present idle and afford, therefore, but poor facilities for study, the data for this paper have been obtained from a study of the Cornwall mines.

From 1877 to 1880 the mines were operated by contractors, who agreed to work under the supervision of a mine-boss, and to deliver to him the ore at one cent per pound, irrespective of its content of metallic copper, the only desideratum to them being that it be ac-

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cepted by the mine-boss under whose inspection it must pass before it was paid for. This method of working, though it secured the company controlling the mines from actual loss, had its disadvantages. Men who carefully dressed their ore were naturally displeased at seeing others that were exceedingly careless about the matter receive the same amount per ton for their ore. The necessary consequence was that all hands soon adopted the plan of dressing the ore as little as possible, the less the better, so long as it was accepted. Nevertheless, during the three years mentioned, the mines paid their owners well.

The system of valuation adopted in 1880—in fact, the only sensible one where contract mining prevails—was to pay the contractor a certain amount per ton for each unit of copper contained in the ore, the price paid being regulated, of course, by the market quotations for ingot copper. Under this system, each lot of ore is assayed and its market value determined before the ore is paid for. Under the old system, contractors delivering 12 per cent. ore, received the same per ton as others whose ore contained 25 per cent. of copper. The injustice of the system was manifest, and as above indicated resulted in a sort of race to see who could deliver the poorest ore and have it accepted.

In 1880 the Cornwall mines, which so far had shipped ore to Baltimore, Boston, and Phœnixville, erected works for making raw matte, and in 1881 refining works were added.

The mines have been in so many different hands that it is impossible to state accurately the total output to date. However, where figures are given, they are taken from the books of the Ste. Genevieve Copper Works and can be relied upon.

In the following pages I shall discuss:

I. The geological formation and modes of occurrence.

II. The geological history of the ore district.

III. The method of working, as illustrated by the Cornwall mines.

I. Geological Formation.

The Quaternary, Coal Measures, Upper and Lower Silurian, and Archaean systems are all more or less developed in Ste. Genevieve County. The Ste. Genevieve copper deposit occurs in the second of the Magnesian Limestone series of the Lower Silurian system. In the immediate vicinity of the mines this rock attains a thickness of upwards of 250 feet. East of the mines the Carboniferous system is met and continues to the river above Ste. Genevieve, while below the

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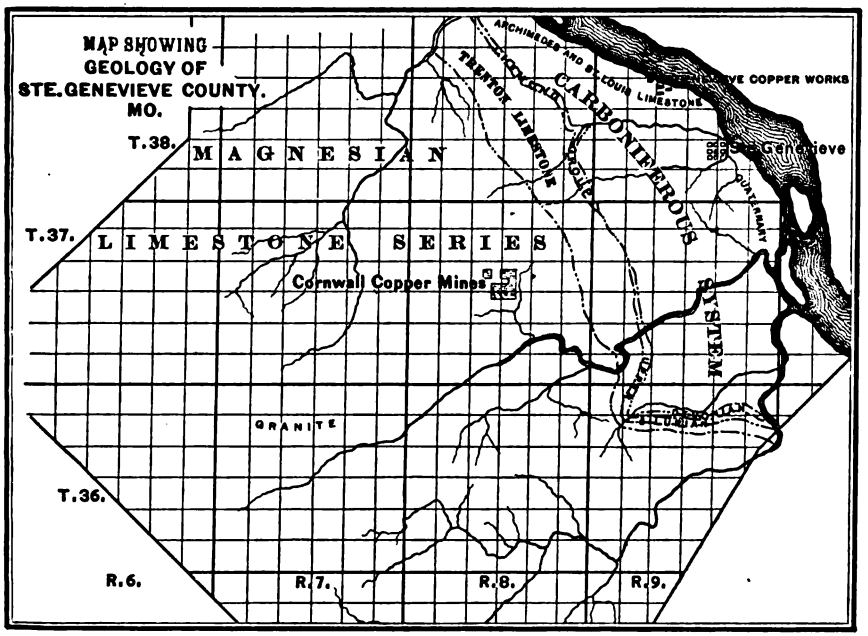
town the Quaternary occupies the half dozen sections included between Dodge Creek, Mill Creek, and the Mississippi River. North of the town the Carboniferous is represented by the Archimedes and St. Louis limestones, and just west of these, the Receptaculite and Trenton limestones appear as representatives of the Lower Silurian, which reaches west into St. François County. There are no outcroppings of Upper Silurian between Ste. Genevieve and the mines. The accompanying map shows the geology of the county. For most of the data I am indebted to Dr. Shumard, who has done the only reliable geological work that has been done in Ste. Genevieve County. I have been



thus exact in the above sketch of the geology of the county for the following reason, viz.: the only work done in Ste. Genevieve County since the discovery of workable deposits of copper was done by Mr. James R. Gage. In his report to Messrs. Rozier, Harris, & Co., in June, 1877, Mr. Gage says: "The geology of the copper ore district belongs to the Upper Silurian formation, which extends far to the west, and reaches to within a few miles of the river on the east, from which point the Carboniferous system occupies the intervening district to the river." This statement I can only suppose an error consequent upon a too hasty examination. One of the plainest guides for the

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determination of geological formations in Southeast Missouri—one easily followed, even by those unskilled in palæontology—is the saccharoidal sandstone, which attains a thickness of more than 40 feet, about 2 miles east of the mines. This sandstone is largely developed in Ste. Genevieve County and is easily recognized. It consists of a remarkably pure white sand, of very fine grit, and, according to an analysis of a selected sample, made in the laboratory of the Ste. Genevieve Copper Works, contains 99.6 per cent. of silica. It has of late been used successfully on furnace bottoms, and for years was shipped to Pittsburgh, Pa., and to Wheeling, W. Va., for glass-making.

The Second Magnesian Limestone consists of a silicious, magnesian limestone, interstratified with seams of chert. Numerous pockets or openings occur in this limestone. The smaller ones are lined with crystals of dog-tooth spar, while the larger ones contain stalactites and stalagmites. The crystals mentioned are never transparent, but are usually translucent, and have a milky or brownish color, the latter being due to the presence of iron. The cavities vary in size from 3 inches to 20 or 30 feet, but 6 feet is about the average length. Crystals of dog-tooth spar 20 inches long are not uncommon.

The chert seams occurring in this formation are from 1 to 12 inches in thickness, and of varying distances apart. The chert is generally hard, breaks with a conchoidal fracture, and has a dull white color. In the drifts, however, it often occurs as a porous, more or less friable mass, termed by the miners "chalk" rock, "cotton" rock, etc. The broken chert is found cemented with calcareous matter, with ore running in seams all through, and often entirely covering the conglomerate mass. The chert rarely contains minute cavities, in which are found small hexagonal prisms, with one end buried in the side of the cavity, the other free, and terminated with a hexagonal pyramid. No large quartz crystals are found.

As far as can at present be determined, the copper deposit consists of two nearly horizontal sheets of ore, between strata of chert, in the limestone. Some difference of opinion, however, exists in regard to this matter. Mr. Gage, in the paper before mentioned, says, "The copper ore occurs in three, possibly four, distinct beds." Mr. Gage's reasons for believing this are not stated in his report, and will, probably, forever remain a mystery. The upper of the two known levels—that from which nearly all the ore has, so far, been extracted at the Cornwall mines—is about 250 feet above the bed of the stream traversing the adjacent ravine.

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The lower level—that worked at the Swansea mine—is at least 150 feet below the upper level. After a careful examination, assisted by surface explorations, I was unable to find any evidence of a third level. No machine drills being used at the mines, no prospecting has been done by boring, and hence the number of levels is not definitely settled. But I would certainly hold, that no one would be justified in asserting that there were "three, possibly four, distinct beds," when evidence of only two existed.

The following ores occur:

(1.) *Chalcopyrite.*—After penetrating the hill to a distance beyond the effect of surface influences—atmosphere and moisture—this ore is found massive, and from 3 inches to several feet in thickness. It constitutes the bulk of the ore now mined. Near the surface it is often found coated with crystals of malachite and azurite. It is sometimes found softened and discolored, so as to look like tenorite. An analysis of such a piece showed it to contain:

Copper,	28.0 per cent.
Sulphur,	31.2 "

This ore, in varying proportions, accompanied by chalcocite and oxidized ores, is found in all parts of the mine. When found sufficiently far in the hill to be free from surface influences it has a brilliant brassy color, which quickly tarnishes upon exposure, forming beautiful specimens of peacock ore.

(2.) *Chalcocite.*—This ore is never found in large quantities. It usually carries about 60 per cent. of copper.

(3.) *Malachite.*—This occurs (*a*) massive, (*b*) as incrustation. When massive it is earthy, and varies widely in the percentage of copper contained, some specimens carrying as low as 11 per cent., while others contain 37 per cent. to 40 per cent. A general average of the carbonates is about 20 per cent. Some pieces are nearly pure, and admit of a high polish when ground to a smooth surface. When incrusting it occurs as delicate fibrous crystals, and is of very little economic value, the incrustation forming but a small fraction of the weight of the ore or rock incrusted.

(4.) *Azurite.*—This occurs as an incrustation only. It is of no economic value, as the amount is exceedingly small.

(5.) *Cuprite.*—This occurs in considerable quantities as seams in sulphide, and occasionally unaccompanied by other forms. In the latter case the ores are silicious and vary in content of copper, from 8 per cent. to 42 per cent. In the former case it has increased the percentage of copper in the chalcopyrite to 45 per cent.

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(6.) *Tenorite.*—Not met with extensively. When found it is impure, containing about 50 per cent. of copper and 13 per cent. of sulphur. It is soft, black, or blue-black, and soils the hands.

(7.) *Chrysocolla.*—Only specimens are found.

The following sections, taken from various parts of the mine, are of interest as showing the mode of occurrence of the ore. Fig. 1

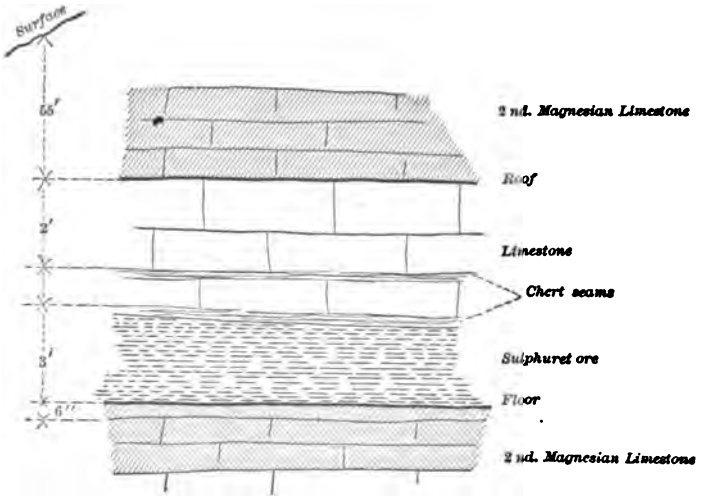

Fig. 1

represents a section in the Shearlock drift, at a point where the ore is unusually solid and free from chert fragments. This section is

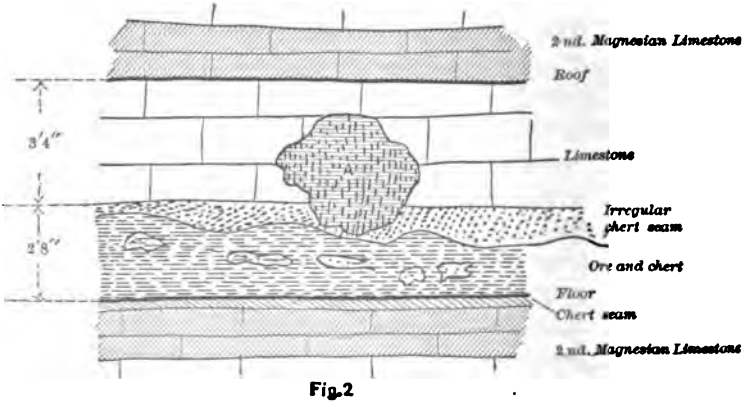

Fig. 2

taken 270 feet from the mouth of the drift; consequently surface influences are but little felt, and the ore is found unaltered.

Fig. 2 represents a section in the same drift, about 60 feet from

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the mouth of the drift. *A*, is a pocket partially filled with silicious clay. These pockets are met with frequently. The ore is here very silicious, as it is filled with pieces of chert and cut out to a considerable extent by sand boulders. These sand boulders consist of an

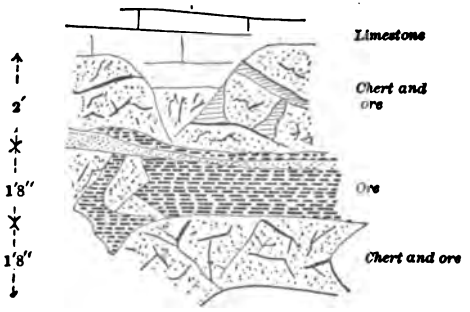

Fig. 3

argillaceous sand of moderately fine grit. No copper has ever been found in them; on the contrary the ore seam invariably thins out where these appear.

Fig. 3 is a sketch from the same drift, showing a common occurrence of the ore. Often the chert is so intimately mixed with the

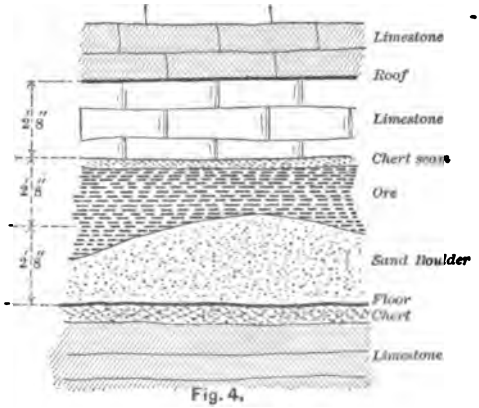

Fig. 4.

ore as to preclude the possibility of anything like effective hand dressing. The ore, in this case, is chalcopyrite, with malachite, azurite, and red and black oxides, the oxidized ores constituting fully one-half. The chert consists of angular fragments, with seams of ore running in every direction. Fig. 4, taken from the same drift, shows the sand boulders above mentioned. The ore seam often

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thins out, from several feet in thickness down to a few inches, and in some cases disappears altogether. The ore represented in Fig. 4 is sulphide, with flakes of carbonate along the planes of cleavage.

Fig. 5 is a sketch taken from the Vallé drift, 235 feet from the mouth of the drift. The ore here is a very compact sulphuret, almost

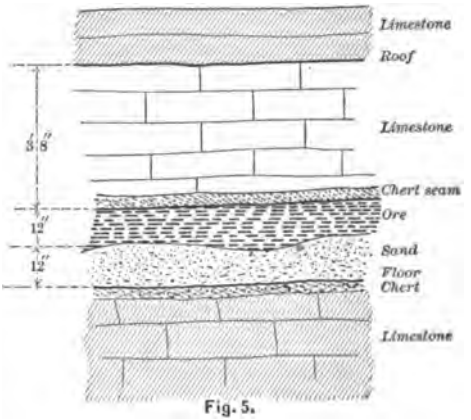

Fig. 5.

free from gangue. About 15 feet from the point where this sketch was taken the ore-seam disappears altogether to reappear further on.

Fig. 6 is a sketch taken at the place where the ore-seam disappears.

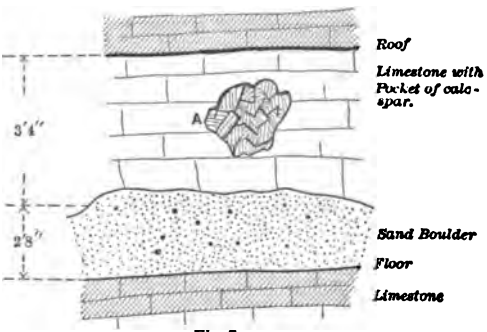

Fig. 6

The sketches given illustrate the various modes of occurrence of the ore, and from a study of them we are enabled to read with considerable accuracy the

II. Geological History of the Ste. Genevieve Ore District.

The geological history is so nearly identical with that of the Southwest Missouri lead and zinc region, that I cannot do better than

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give the history of the latter in the words of Dr. Schmidt (see Missouri Geological Survey, 1873–1874), with such changes as to render the matter applicable to the former.

The geological history of the Ste. Genevieve copper deposit may be divided into five periods, as follows:

(1.) *Period of Deposition.*—During this period a silicious limestone was deposited. While this was still calcareous ooze, the chert segregated out in numerous thin layers, occasionally containing milky quartz. This deposit probably remained unaltered for a very long time, and became hard, dry, and dense before the second period began.

(2.) *Period of Dolomization.*—During this period dolomization of the limestone was accomplished through the agency of magnesian waters percolating through the strata and depositing magnesium carbonate. The principal deposition of ores, from watery solutions, as also the disturbances and ruptures in the chert, in consequence of the contraction of the limestone, belong to this period. The dolomization of the limestone, and the simultaneous deposition of the ores, began from horizontal crevices, and then extended through the whole mass of one stratum of limestone, and was limited by the layers of chert above and below. This process was going on in precisely the same manner at the different levels.

(3.) *Period of Dissolution.*—This period is not so marked in Ste. Genevieve County as in Jasper and Newton; yet the numerous fragments of chert, the large amount of clay, sand, and rotten silicious dolomitic limestone occurring in the drifts, show plainly that there has been such a period. The final deposition of ores probably took place toward the close of this period. There is no doubt that ores were deposited after the accumulations of chert were formed, as chert is often found entirely covered with chalcopyrite. Pieces of chert are also cemented together with ore.

(4.) *Period of Regeneration.*—Local regeneration of the partially dissolved and softened limestone, by renewed deposition of carbonate of lime, local infiltrations of silica, and possibly a continued deposition of ores, belong to this period. All the conglomerates, which consist of chert fragments cemented by either a silicious or by a calcareous mass, were formed in this period.

(5.) *Period of Oxidation.*—During this period the sulphurets were changed to oxides and carbonates. This is specially noticeable near the surface; but so far has the oxidation been carried, that in the east drift, specimens of malachite and tenorite were obtained 400

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feet from the mouth of the drift. The shells of brown hematite were formed, during this period, from the oxidation of the pyrites. Near the surface these shells are very numerous. This period, of course, reaches up to the present day.

III. Method of Working.

The Cornwall copper mines are situated in T. 37 N., R. 8 E., in Ste. Genevieve County. They occupy parts of sections 15, 16, 21, and 22, and comprise altogether 310 acres. The immediate vicinity of the mines is hilly, the surface consisting of limestone, which has been considerably eroded, the crests of the hills being several hundred feet above the beds of the streams traversing the adjacent ravines. The dip of the limestone is about 5° east.

The district is fairly timbered, and the valleys are well suited for agricultural purposes. The mines are 10 miles from the town of Ste. Genevieve, and 12 miles from the smelting works, which are located at Rock Haven, the landing for Ste. Genevieve, boats being unable to land at the town on account of a sand-bar which has formed in front of the place.

There is no railroad nearer than the St. Louis, Iron Mountain, and Southern Railroad, which passes through St. François County. All transportation of ore, from the mines to the smelting works, is, therefore, by means of wagons.

The roads, from the mines to the works, are for the most part of red clay, and during wet weather are almost impassable for heavily loaded wagons. In dry weather, however, they are very good, comparing favorably with country roads elsewhere. With but little labor and expense they could be greatly improved. The gravel, so plentiful in Ste. Genevieve County, would be excellent for this purpose.

At the mines there has sprung up a small village, containing twenty-one dwelling houses, besides ore sheds, blacksmith shops, and dressing sheds. In honor of the owner of the mines, the town has been named Harrisville.

Each dwelling-house contains one room, 16′ x 18′, with kitchen in rear. The cost of erection of these houses is one hundred dollars. They are rented to miners with families at two dollars per month.

There is abundance of good water about the mines, and one or two springs strong in sulphuric acid. With each house there is a piece of ground for raising vegetables. The wages paid are from $1.10 to $1.35 per day, the former being paid for dressers, the latter

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for miners. This enables the men to live very comfortably, as it is paid in cash, the mines owning no store. The cost of the necessaries of life is moderate. In February, 1882, supplies cost:

Pork,	$0 14 per pound.
Butter,	25 "
Sugar,	12½ "
Flour,	4 00 per 100 pounds.
Potatoes,	1 60 per bushel.
Cornmeal,	1 60 "
Chickens,	15 each.
Coffee,	20 per pound.
Beans,	7 "
Tomatoes (canned),	7 "

Altogether there are seventy-four men employed in and about the mines, exclusive of teamsters. The men all begin work at 7 A.M. The dressers work until 6 P.M., while the miners quit as soon as they have finished a fair day's work. This is now recognized to be 12 feet of drill holes for two men,—a striker and a holder. No machine drills are employed.

The drills used are $\frac{7}{8}''$ octagon steel with $1\frac{1}{4}''$ bit. Each drift is under the immediate charge of a contractor, who agrees to work under the general supervision of a mine superintendent, and to deliver to him the ore at the rate of $1.50 per unit, when ingot copper is worth 20 cents per pound in St. Louis. This amounts to 7½ cents per pound for the copper contained in the ore, and leaves the works the neat little margin of 12½ cents per pound. The assay is invariably made in the laboratory of the smelting works, and no appeal can be taken from the decision there rendered. 1.3 per cent. is deducted from the wet assay to make up for the losses in smelting.

The hauling from the mines to the works is done by contract. It costs $2.50 per ton all the year round.

The present output of the mines is 150 tons per month. This could be doubled by putting on a night shift.

The drifts are run in on the outcrop, 4 feet wide by 6 feet high, the cost of driving being $6.50 per linear foot. When the ore-faces show well in the drift, chambers are laid off and worked out. The roof is usually kept sufficiently high to enable a man to stand erect in the drift. In places this height is greatly exceeded on account of the upper strata being too weak to support their own weight.

A part of the wastage is stowed in the old workings. The remainder is carried out on the dumps.

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The ore is kept on the floor of the drift. The rock is stripped from the ore for several days, and the ore is then lifted by means of gads, or, if it be very solid, a light charge of black powder is employed to raise it.

Giant powder (Atlas No. 2) and black powder are the explosives used in blasting. Glukodine was used for a short time with great success, and its use was discontinued only on account of the prejudice of the miners, who, as a class, are always opposed to the introduction of anything new.

The ore and a large amount of waste rock are removed from the mines by means of tram-cars, which run on wooden tramways, and are pushed along by boys. Each car has a capacity of about 500 pounds of ore. The ore is delivered by these cars at the dressing-sheds, where most of the adhering rock is removed. When carefully dressed the ore carries 25 per cent. of copper. Ordinarily, the ore as delivered at the smelting works carries about 18 per cent. For the year ending December 31st, 1881, the average content of metallic copper, in all ore delivered to the smelting works, was 18.1 per cent. The principal portion of the gangue remaining with the ore is chert, and hence, when delivered at the works, the analyses of the ore often shows 50 per cent. of silica.

No educational facilities are at present offered; but it is thought that a school will shortly be established for the benefit of the children of the miners.

The cost per ton of the ore delivered at the smelting works, supposing it to carry on the average 18 per cent. of copper, is:

Mining and dressing, at $1.50 per unit, ...	$27 00
Supervision, weighing, etc., ...	0 33⅓
Hauling, ...	2 50
	$29 83⅓

The market value of such ore, when copper is quoted at 20 cents, is $3 per unit, or $54 per ton. Net profit to owners, $24.16⅔ per ton.

HOEFER'S METHOD OF DETERMINING FAULTS IN MINERAL VEINS.

BY R. W. RAYMOND, PH.D., NEW YORK.

I DESIRE to call the attention of members of the Institute to a new method of plotting and determining faults in mineral deposits, suggested by Prof. Hanns Hoefer, lately of the Mining School of Przi-

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bram, and now of the School of Leoben, and one of the editors of the Austrian *Zeitschrift für Berg- und Hüttenwesen*, in the 29th volume of which appears his paper on the subject. I will here give an abstract of its contents, which, though partial, will be, I trust, sufficient for my purpose.

In the examination of a fault, we usually follow the rule of Zimmermann, which assumes that the hanging-wall of a faulting-fissure has slid downward in the direction of its dip; but dislocations (of coal-seams in particular) show many cases in which one part of the seam has been shoved over the other; that is, the hanging-wall of the faulting-fissure has slid upward instead of downward. For a long time, every dislocation of a mineral deposit upon a cross-fissure was regarded as necessarily belonging to either one or the other of these two classes. It was either a slide (*Sprung*) or a heave (*Wechsel*). But it has been proved of one and the same fault that it may appear at one place to be a slide, while at another place, even in the same mine, it appears to be a heave.

This phenomenon itself suffices to show that the classification of dislocations is not so simple as has been supposed, and the methods pursued by mine surveyors, based upon that classification, may therefore need improvement. These methods, as is well known, assume that throughout a given fault the motion of the hanging-wall has been everywhere the same, and consequently that the so-called vertical interval or "throw," determined by exploration of the two dislocated parts of the deposits at any one point, is a guide for exploration at all other points. Practice, however, shows that this guide is not unerring. It does not always agree with the indications of actual movement and direction furnished by the striations of the walls of the faulting-fissure. These marks frequently do not follow the dip, but lie obliquely across it. The oblique or other motion thus indicated is certainly one of the elements in the geometrical problem presented to the surveyor.

Fig. 1 may illustrate this point. Let AB be the line of intersection between the vein L and the faulting-fissure V, the striations of which indicate that the movement took place in the direction of CD. The dislocated continuation L' of the vein being found at EF, the old rule would declare that the case was one of a heave or upward movement of the hanging-wall; and yet it is really an oblique slide. That the distinction is important appears when we consider that, if the vein being worked in the foot-wall of the faulting-fissure had contained an ore-body which was cut off by the fault at G, the old

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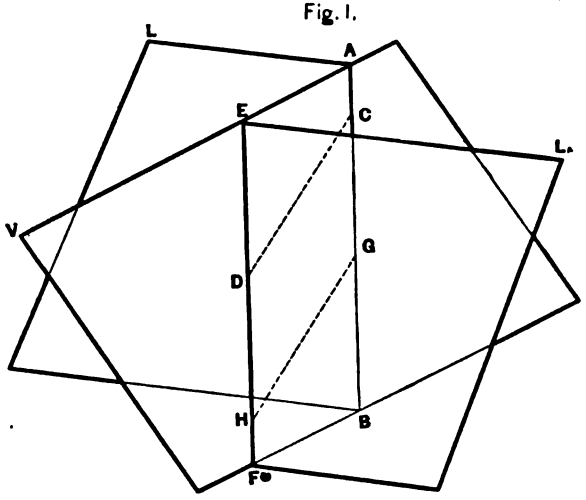
rule would require us to accept the continuation of this ore-body at some higher point in the hanging-wall of the fault; whereas, by the present hypothesis, it is at the lower point *H*, to which the striations tend. It is apparent that an oblique slide would not, according to the old rule, appear to be a slide at all, unless the striations (that is, the actual movements) were steeper in dip than the lines of in-

Fig. I.



tersection. In case *L'* had been horizontally moved, the dislocation would, by the old rule, be a slide, if it had moved in one direction, and a heave, if it had moved in the other; whereas, in reality it would have been neither.

But Professor Hoefer goes further, and declares that the parallel uniform movement of the hanging-wall of a fault is not to be always assumed. The evidence of this statement is drawn especially from coal-seams; not, as I apprehend, because the dislocations of these deposits are different in nature from those of metalliferous veins, but because coal-mining has furnished more extensive excavations, and therefore a greater body of evidence than any other branch of the business. Moreover, we can with greater certainty judge what was the original position of a coal-bed than we can of a fissure-vein. When the latter suddenly changes dip, for instance, beyond a fault, we cannot be sure that the change of dip did not exist before the dislocation took place. This phenomenon of a change of dip and also of strike is frequent in coal-fields, under such conditions as make it reasonably certain that neither the original position of the coal nor irregularities in the faulting-fissure were the cause; but

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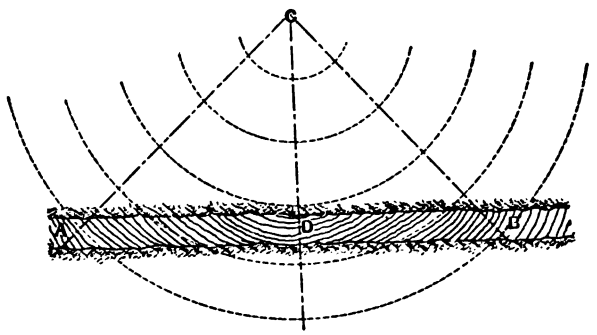
rather that the relative movement of the two parts of the deposit was not in parallel lines. In many cases where veins show a uniform dip, that is, approach in form a regular plane, and yet exhibit these changes beyond a fault, it is reasonable to infer, instead of a simple slide or heave, a partial revolution of the mass on the hanging-wall side of the fault around an axis normal to the plane of the faulting-fissure. A simple geometrical construction will show that when one mass of rock has moved in this manner upon another, the dislocated portion of the mineral deposit common to the two must acquire a different strike and dip from that which has remained unmoved. Professor Hoefer cites as an illustration a very extensive fault in the

Fig. 2.



neighborhood of Aix, which shows to the southeast a greater vertical dislocation than toward the northwest, and can only be explained by a turning movement.

Fig. 2 shows how, in the simplest case, that of a revolution without vertical descent or ascent of the hanging-wall, the striations in the faulting-fissure may indicate the axis of the revolution. In this figure, *AB* is a drift run in the faulting-fissure, and showing striations according to the dotted lines, which pitch in one direction at *A*, and in the opposite direction at *B*. In such a case, the centre of movement would be found at the intersection of perpendiculars drawn through the line of striations. Thus, if striations were exposed at *A*, *B*, and *D*, the intersection of the perpendiculars would show the centre of movement to be at *C*. In practice, however, it is likely that the several perpendiculars drawn through such striations would not intersect at a given point; and this would show that, besides the turning movement, there had also been a movement of translation of the whole mass, up, down, or along the plane of the fault. The complication of these two movements is, however, not beyond analy-

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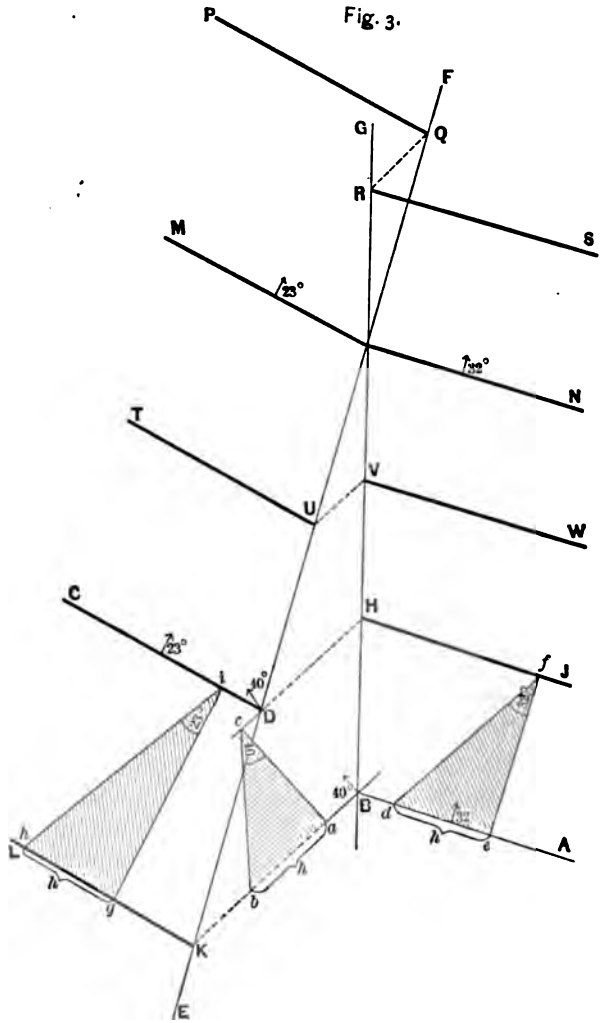
sis, if the data are sufficiently abundant and exact. Even with the imperfect data usually afforded by the limited exposures in mines, it is much better to work upon a perfect than upon a crude and partial system; and Professor Hoefer thinks that not only the points already

Fig. 3.



mentioned, but also the question of direction of movement (for example, in Fig. 2, whether from *B* to *A*, or *A* to *B*), can in many cases be satisfactorily determined by the plan he proposes.

This plan may be illustrated for a general case by Fig. 3. Let *AB* represent the course of a vein dipping 32° (as shown by the ar-

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row), which has been explored on an upper level to where it is cut off by a cross-fissure, having the strike *BK* and the dip of 40° (as shown by the arrow). Let it be assumed that upon a lower level the vein had been opened, with the strike *CD* and the dip of 23°; that on this level a fault was encountered at *D*, having the same strike and dip as that at *B*. By a simple construction, with the help of the triangle *abc*, in which the angle *c* is 40°, and the side *ab* is the vertical distance *h* between the two levels, we find the point *c* and draw the line *cD*, which, being parallel to *BK* and also coinciding with the strike of the fault at *D*, proves the latter to be identical with the fault at *B* on the level above. We now determine the two lines of intersection *EF* and *BG* made by the fault, with the two portions *AB* and *CD* of the faulted vein. This can be done most easily by the aid of the two triangles, *def*, *ghi*, in which the base *h* is taken equal to the vertical distance between the two levels, and the angle opposite *h* is, in each case, the angle of the dip. *AB* and *CD* being already given, the corresponding lines, namely, *HJ* on the level of *CD*, and *KL* on the level of *AB*, are to be found. This is done by drawing *HJ* parallel to *AB* through the point *f*, and prolonging *hg* parallel to *CD*. The course of the fault at *B* is known; hence the line *BK* drawn on that course intersecting the line *KL* at *K* determines the point *K* for that level, while for the next lower level the point *H* is determined by producing the line *CD* parallel with *BK*; in like manner, the lower levels, *TU*, *VW*, *MON*, *PQ*, *RS*, etc., can be plotted. It is evident that, by drawing lines through *KD* and *BH*, the lines of intersection *EF* and *BG* are obtained. It is evident also that on the fourth level *M*, if in working from *M* the fault is encountered at *O*, it will not be necessary to cross-cut, as in the upper levels, to find the continuation of the vein; since at that point, which is the centre of revolution, the vein can be found by simply breaking through the cross-fissure. In the next lower level, *PQ*, however, if the fault is encountered at *Q*, it will be necessary to cross-cut for the continuation of the vein in the direction *QR*, a direction opposite to that which would be necessary at *U* or *D*.

It will be seen that in this case a revolution has been demonstrated without the help of the indications afforded by the striations.

Professor Hoefer indicates also how this graphic method may be applied to lines of intersection which are not straight, but curved; and to the still more complicated case of a varying strike at different levels in the faulting-fissure itself; that is, for instance, when *BK*, *HD*, *VU*, and *QR* are not parallel. He says in substance:

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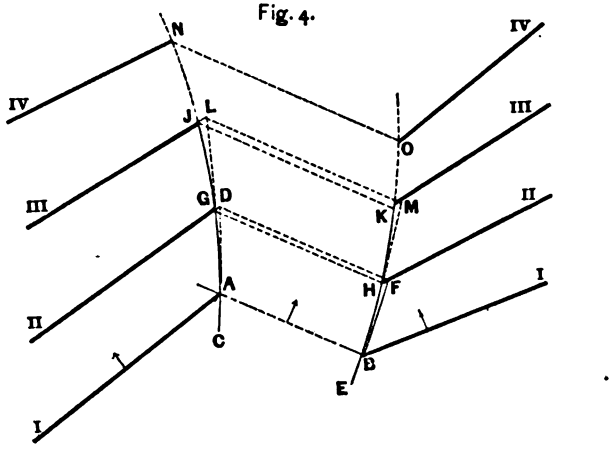
"The solution of the problem remains in principle the same when the lines of intersection are curves. If, for instance, we had plotted a fault for different levels (not too far apart vertically), and had found the facts on actual exploration to differ from our construction,—that is, the lines of intersection, imagined as drawn in the plane of the fault (such as *BK*, *DH*, etc., in Fig. 3), had proved in practice to be longer or shorter than required by our construction, we should then obtain a number of elements of the actual curved lines of intersection, which we could prolong according to their curvature, in order to operate further with them, just as if they were straight.

"To take an example: suppose (Fig. 4) that the fault had been encountered on level *I*, in the two portions of the vein, at *A* and *B*, giving at these points the straight lines of intersection *AD* and *BF*; but that on level *II* the fault was found

Fig. 4.



at *G*, not *D*, and the continuation at *H*, not *F*. Straight lines drawn from *A* through *G*, and from *B* through *H*, thus become the lines of intersection for the construction of the fault on level *III*. But actual developments show the points sought, to be *J*, *K*, instead of *L*, *M*; and, in short, we become able to prolong the curves *AGJ*, *BHK*, as curves, and thus, to obtain for lower levels, in advance of exploration, more accurate determinations."

Professor Hoefer recommends in practice the general method above described, on the ground that it involves no generic assumption or hypothesis, but makes the work of the surveyor in the first place purely descriptive, and also checks by graphic construction the errors of observations due to irregularities in the vein and fault. He points out also that this method indicates conclusions as to the nature of the movement which has taken place; since, if the two lines of intersection are parallel, the movement must have been parallel; while if they converge, the movement must have involved a revolution, and the points where they intersect must be the intersection of the axis of revolution with the plane of the fault.

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This statement of Professor Hoefer's method suggests the following observations:

Evidently the graphic method shown in Fig. 3 will not indicate, in case of a compound movement, involving both a revolution and a slide, either the existence, the direction, or the amount of the latter. The relative position of the two parts of the faulted vein, shown in Fig. 3, may have been reached by a simple revolution around an axis normal to the fault at *O*, or by a revolution around some other axis normal to the fault, coupled with a slide along the fault. For instance, the axis of the revolution may have been at *U*, and the slide may have carried it *apparently* to *O*.

Yet this is precisely the case which may be expected to be most frequently encountered in practice. Simple revolutions must be rare, if, indeed, they ever occur. My own impression on this point is confirmed by the reply of Professor Hoefer to an inquiry which I addressed to him after perusing his paper. He says:

"Circular movements, combined with movements in straight lines, are very frequent in our faults; in fact, I do not doubt at all that a continued careful study will show them to be the rule. Whether simple revolutions often occur, is very difficult to decide, from the observations thus far available. You know how one-sided and incomplete the inquiry has heretofore been in this direction. In the southernmost district of Przibram, the Clementi vein shows in its selvages striations, the varying directions of which indicate a circular movement; and my studies (unfortunately interrupted by my departure) led me in this case to the belief that the movement had been circular only. But I did not consider the question definitely settled."

But, to return to the illustration of Professor Hoefer's method given in Fig. 3, it is evident that although the method, applied, as in that case, to a fault which has been determined in two places, at different levels, will not, from these data alone, reveal the exact components of the movement which has taken place, it will nevertheless indicate for any level the point where the continuation of the vein is to be sought, beyond the fault. It is, however, often important to find the continuation, not merely of the vein, but also of an ore-body in the vein. Thus, in Fig. 3, the miner working from *C* to *D*, and finding the vein cut off by the fault, might know that by drifting in the faulting-fissure to *H*, on the same level, the vein would again be struck; but the point *H* would not in any case (except that of a simple and perfectly horizontal movement) be the point originally adjacent to *D*, before the faulting took place; and if there were at *D* a valuable ore-body, the question would still remain, in what direction from *H* the continuation of this ore-body should be sought.

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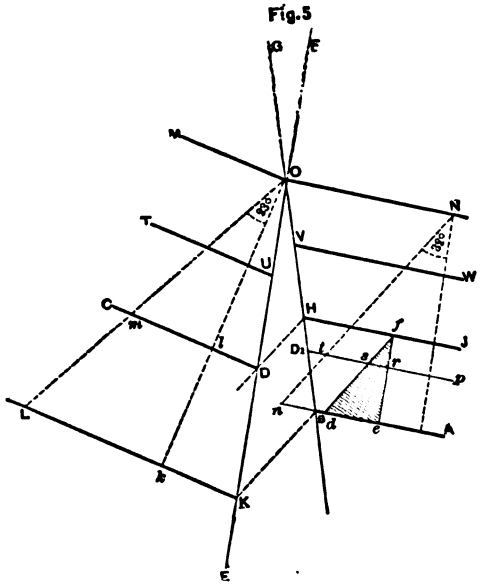
For the case of a simple revolution around O, the solution of this question would be easy. It is shown in Fig. 5, which I have made by taking part of Professor Hoefer's Fig. 3, and adding two auxiliary triangles, OLk and NnA. The construction is as follows: From O, draw Ok perpendicular to KL, and OL, making the angle $LOk = 23°$. Similarly construct from any point N on ON the triangle NnA, making the angle at $N = 32°$. The distances cut off on the hypothenuse OL by the lines LK, CD, and TU, represent the heights (inclined measurement) between these levels. The same is true of the sections into which Nn is divided. The distance of D above the level MO, along the dip of the vein, is Om; and the

Fig. 5



point adjacent to D, before the dislocation, must lie at the same distance above ON. Taking $Nt = Om$, and drawing Dp through t, parallel with HJ, we have D_1, the point desired, which lies the distance fr vertically, or fs, inclined measurement, above HJ.

But if there has been a rectilinear as well as a circular relative movement of the vein masses on either side of the fault, the point D_1 will not be the point formerly adjacent to D. The continuation of an ore-body cut off at D will lie at a distance and in a direction from D_1 directly dependent upon the extent and direction of the rectilinear movement. (I need hardly say that in all these cases it is

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of no consequence whether both walls, or only one actually moved. The total movement may be assumed to have affected one wall only.)

In this case, the study of the striations in the faulting-fissure may give valuable, though perhaps rarely exact, indications as to the direction of movement. If the rectilinear movement followed the circular one, the striations may furnish a clear record of it in straight lines. If the two were (as is more probable) simultaneous, the striations would be strictly epicycloid curves; but for their interpretation it would be sufficiently accurate to consider them as fragments of ellipses, having their major axes inclined in the direction of the rectilinear movement. These indications would doubtless be in most instances of practice merely general guides to exploration. But after, by such exploration, the continuation of a given ore-body (as D, Fig. 3) had been found, it is plain that the whole movement of the faulted vein could be analyzed and plotted, and that the continuation of any other ore-body could be sought with confidence. In the case before us, it would be only requisite to determine the relations of the point actually found to D_1, its theoretical position on the hypothesis of purely circular motion; and the correction thus applied to D_1 could be applied to any other point similarly determined.

I should remark, in conclusion, that all these constructions rest upon the assumption that the dip of each segment of the faulted vein is constant. That is, the vein is treated as a plane. But it would not be difficult to include, in the method here shown, changes of dip and strike, as these might be discovered in actual working; and under certain circumstances, a change of dip might serve as a useful landmark in surveying. For instance, if, in Fig. 3, there were a change of dip in the left-hand portion of the vein, at the level CD, then the corresponding change of dip must be shown on the line GB, at the point formerly adjacent to D; and the discovery of this point would at once, as has been already shown, permit the analysis of the movement which had taken place, and the deduction of all its resultant relations.

THE OCCURRENCE OF GOLD IN THE POTSDAM FORMATION, BLACK HILLS, DAKOTA.

BY WALTER B. DEVEREUX, E.M., GLOBE, ARIZONA.

THE special conditions under which gold occurs in the Potsdam formation of the Black Hills present features worthy of a more systematic presentation than they have heretofore received. The notes

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which are comprised in this paper relate to the immediate vicinity of the Homestake vein, where are found the only deposits of the character referred to which have heretofore attained any importance as gold producers. At this point the oldest visible formation comprises the highly metamorphic palæozoic schists, which contain the gold-bearing quartz veins. Resting unconformably upon the schists is a sedimentary formation composed of débris derived from the schists, and containing the evidences of the life of the Potsdam period. The base of this formation is generally a conglomerate, which, at the Homestake vein, is very thin or absent entirely. Its section here is that of a wedge, the thin edge of which comes nearly to the Homestake vein.

Early in the history of the Black Hills much excitement was caused by the discovery of gold in paying quantities in the lowest stratum of the conglomerate above referred to. The ore was readily obtained by a system of horizontal drifts, and many hundred thousand dollars were obtained in a short time. Owing to the peculiar character of the ore the mines were known as cement mines, although the material was a true conglomerate, generally hard, and needing the stamp-mill for reduction. The larger number of these deposits were found upon the eastern side of the Homestake vein, and within a perpendicular distance of about a mile. Only one paying deposit has been worked upon the western side. At present the larger number have ceased producing, and it is not probable that they will ever attain the importance that they have had, since the productive territory has been quite extensively prospected. The conglomerate, in places, partakes of the character of a breccia, and generally gradually merges, in the upper strata, into sandstone, or, where there has been local metamorphic action, into quartzite. The mass of the conglomerate is a mixture of quartz boulders and pebbles, and worn fragments of schist, with frequent pebbles of hematite. While there is a slight slope away from the Homestake vein, such as would be natural in a beach, the contact of sedimentary and schistose formations is essentially a plane with a slightly undulating surface, due to the unequal durability of the underlying formation. Gold occurs in these sediments in two distinct conditions, viz.:

1. Gold as a mechanical constituent.
2. Gold as a chemical constituent.

Under the first head I class the principal portion of the cement gold which has been mined, while under the second head I wish to speak, in the latter part of this paper, of some gold ores of an entirely

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distinct character, which are found some few miles distant in the same formation. I am aware that in classing the gold of these conglomerates as a purely mechanical constituent, I am doing so in opposition to a theory, recently upheld by an elaborate argument, which endeavors to prove that placer gold is a product of local precipitation or crystallization.

Careful observation in the field and a consideration of the facts, have, however, led me to reject this theory as untenable and incompetent to explain the conditions noted, and I hope in this paper to present evidence which shall justify this conclusion. The horizontal character of the sediments and the fact that their accompanying life-forms belonged to salt-water types lead us at once to the conclusion that they were ocean sediments and not river beds, and that they were formed in very shallow water, where there was strong wave action. The thinness of the deposits near the Homestake outcrop and the coarseness of the material indicate that they were beaches. The absence of gravel over the quartz outcrop shows that it was either insular, or perhaps a shallow reef.

We know that this absence of gravel is not due to more modern erosive action, because the eruptions of porphyry occurring in later geological times, and yet before the modern valleys were scoured out, have capped over the vein outcropping, and preserved it intact in many places.

This same porphyry has also overflowed the Potsdam sediments, thus giving us the proof that they were originally as shallow as they now are. In some places we have at least a hundred feet of conglomerate over the gold-bearing material, but generally much less. In order to show that the Homestake vein was large enough to have supplied gold for all these deposits, I need only mention that its outcrop, as covered by the porphyry, was at least a mile in length, and from one to two hundred feet in width, of solid, gold-bearing material.

Much of the conglomerate has been cut away by the formation of the present topographical conditions, and we can only construct the original contact plane by noting the different points at which it intersects what are now hills.

The appended sketch is an approximate section taken perpendicular to the Homestake vein and extending eastward to the limit of the gold-producing territory; in all, perhaps a mile and a half in length. It shows how small a portion, comparatively, of the old sea-bottom remains. From it we see, also, that the site of Central City was

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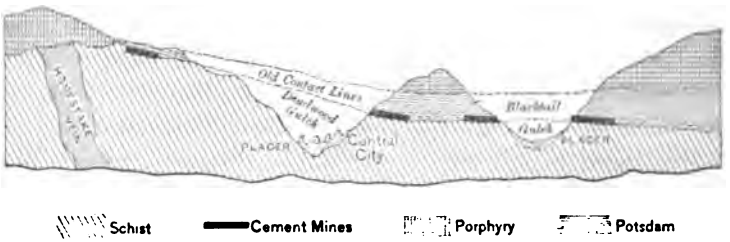
once overlaid by a placer—probably richer than the mines in the hills on either side, which have yielded so much gold. The contact plane has a dip of about ten degrees away from the Homestake vein. First considering the gold which remained in the matrix of gravel, we will afterward endeavor to show what became of the gold again set free during the disintegration of the conglomerate. The larger



Approximate Geological Sketch from Homestake Vein, Eastward.

portion of "cement gold" (using the local term for convenience) has been taken from the ridge shown in the sketch between Deadwood and Black Tail gulches.

Ore mined from this ground is said to have milled as high as fifty dollars per ton, and the stratum lying close to the bed rock was exceedingly rich, as is generally the case where the ore pays at all. Small channels and depressions caused local concentrations, and these channels were generally followed in the process of mining. The ore was hard, and generally required blasting. This condition was very advantageous in studying the character of the deposits, since large blocks could be taken out and examined in detail. If the term might be used in such a sense, these were fossil placers, in which the most minute relations were carefully preserved, although originally existing in a very unstable material.

Many of the facts here noted were obtained while running some hundreds of feet of drifts through one of these ore-bodies.

In general we find much the same variations of quantity as are shown in the ordinary gravel placer. The local channels referred to show the same alternations of rich and poor material, due to different conditions of current, and the universal occurrence of the greater part of the gold near the bed rock. In general, only five or six feet in thickness will pay for mining and milling. Our method of assaying was by pounding the sample in a mortar and washing the pulp in a pan. The gold had all the characteristics of placer gold, and was generally what is called shot gold, or smooth rounded grains,

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slightly flattened. I observed one nugget of nearly three pennyweights in weight.

The cementing material of the conglomerate was generally oxide of iron, and the gold which had lain on the bed rock was often attached to the overlying boulders by this medium. In general, where conditions had been such as to allow the subsidence of other materials of high specific gravity, the gold was most abundant, ordinarily with large quartz boulders or with pebbles of hematite. The latter were seldom found without gold being attached to them, the pebbles themselves having a smooth, polished surface. In general, the position of the gold was always such as to point to its great specific gravity as the locating cause, and not to solution or precipitation. In fact, the many curious positions in which I observed the gold were such that no satisfactory explanation could be found except the one noted above. Upon one quartz boulder, which had lain directly upon the schists, I found, after removing the decomposed talc from the bottom, that grains of gold of almost exactly the same size were arranged in ribbon-like layers in such quantity that half an ounce could probably have been covered by the hand. Each grain of gold is generally covered with a thin coating of oxide of iron, which needs a blow to loosen it.

The richest ore is not always found in the deepest portion of the channel, but sometimes upon one slope, the maximum richness being perhaps half way up the slope of the channel.

Small basins or enlargements in these channels are sometimes found, which are perhaps one hundred feet across, in which the gold has been deposited in larger quantity. These have the appearance of having been formed by whirlpool action.

The fineness of this gold is greater than that of the quartz veins, as is generally the case with placer gold. This is a perfectly rational condition, since from the time it is liberated from the vein the gold is subjected to the action of various chemical agencies, which naturally act more energetically upon the silver than the gold of the alloy. In the case of the gold in question, we have not only the ordinary conditions, but the added ones that must have resulted from the saline waters, and the solutions of iron which produced the large amounts of oxide of iron noted. In one case the latter amounts to a bed several feet in thickness, lying over the gold cement. Combined with these chemical agencies was the heat produced in later times by the porphyritic intrusions and overflows.

Having exposed one of these dikes which, for several hundred feet,

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cut through cement, I was surprised to find that gold was seldom present in close proximity to the porphyry, although the conditions of bed rock were favorable. This indicated that there had been a powerful solvent of gold present. This was further shown by coarse pieces of gold, which, though similar in shape to others, had exchanged the smooth, worn surface for the corrugated surface known as oxidized, and produced by subjecting the metals to the action of a solvent. These pieces, however, showed none of the ramifications or planes ordinarily seen in crystallized metals.

Since the solution of silver must have been confined, to a certain extent, to the surface, I made some tests to determine whether small, thin pieces of gold which had proportionally the greater surface, did not contain less silver than the coarser particles.

The following assays were obtained:

	I. Coarse gold.	II. Coarse gold.	III. Fine gold.	IV. Gold bullion.
Gold, ...	.902	.893	.917	.915
Silver, ...	.098	.107	.083	.085

The bullion was produced from the same mine as the other specimens, and is reduced to the pure alloy for comparison.

While it is to be regretted that more specimens were not assayed, the theoretical result is obtained as indicated, the bullion being a mean between the two extremes, as is likewise natural. Under the given conditions we should expect that the gold could not, by any possibility, have retained its original content of silver, and in this connection it will be interesting to compare the relative proportions of gold and silver in the bullion produced from the different portions of the Homestake vein.

The figures were given me by my friend Mr. George H. Hewitt, whose employment in the metallurgical department of these mines for several years is a sufficient guarantee of their accuracy.

They commence at the Homestake end of the vein, giving the bullion assays of the various mines upon the vein in regular order.

	Homestake.	Highland.	Terror.	Deadwood.	De Smet.
Gold, ...	.820	.830	.825	.850	.820
Silver, ...	.170	.155	.160	.140	.170

It will be seen at a glance that the proportion of silver is much greater than in any of the placer specimens examined. To make the proof of the above proposition conclusive, it should be shown that the surface of the gold contains less silver than the interior, at least

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in the larger grains. I endeavored to determine this point, but failed to obtain any result owing to lack of time. As to the size of the gold particles, I have seen larger pieces in the Homestake quartz than any that I have known to come from the cement.

While the facts thus far seem to be in accord with the position taken, we have another source of proof, in that we find in these same conglomerates, gold which has undoubtedly been precipitated from solution *in situ*. I have several times split open pieces of decomposed talcose schist, and found in the cleavage plane a continuous thin film of gold. These schists, owing to their porous nature, would easily have yielded up this gold to a solvent, and they were not of the character which generally contain gold in the veins. Moreover the schist underlying one of these deposits has been found to carry sufficient gold to pay for milling, although after a depth of 10 feet has been obtained, it seems to give out. Specimens from this locality show the gold in thin flakes, seldom coarse; and pan tests show the gold to be fine like dust. On the other hand, where the slate has been very soft, cement gold will be found to have worked down into the crevices for several feet. It can be washed out in a pan from the fragments without crushing, and then appears like smooth brown gravel, so continuous is the coating of red oxide of iron. In addition we have gold undoubtedly precipitated in the quartzites of the series at a period much more recent, and this gold presents none of the characteristics of the cement gold. The indications derived from these facts seem to be that when gold dissolved is precipitated again it does not ordinarily take the form of grains. We have seen that this cement gold remained undisturbed through a long geological period, and that it was only set free by the erosive agencies which united to form the present topographical conditions. We can then regard the Potsdam sediment as a storehouse of the gold that it received, finally yielding up the larger proportion to the mining agencies of nature, and retaining the rest until the present time. The question consequently arises—what became of the gold a second time set free? The answer most natural points to the great Deadwood Gulch placer as the second resting-place of this gold. Once concentrated by the waves of the sea, it was a second time concentrated by the action of running water. The upper end of the Deadwood Gulch placer occupied the space directly under the old gravel sheet, which I have indicated as stretching continuously across from the vicinity of the Homestake vein. While from its location it would naturally have received the gold set free from the conglomerate above, there is also

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positive evidence that it did receive and preserve it. An old placer miner told me that much of the gold from the upper end of the gulch had the shell of oxide of iron similar to the cement gold, but that this became less frequent as the gulch was followed down. While it is possible and probable that this placer received gold in later times direct from the Homestake vein, the Blocktail placer in the next gulch beyond is entirely cut off from that source by the deep Deadwood Gulch, and could not have received gold either in solution or mechanically after Deadwood Gulch was once commenced. But it certainly was once overlaid by the Potsdam placer, since rich cements have been found outcropping upon either side, and in all probability all of its placer gold came across by means of wave action and ocean currents, while the underlying rock was as yet unbroken by transverse valleys. We have seen that the Homestake outcrop was protected by a coping of porphyry after it had been washed by the Potsdam seas. At three points this has been cut away by erosion, forming gulches which cross the axis of the vein. One of these is nearly central, and the others are at either end of the outcrop. The amount of vein matter removed by this more recent erosion is measured by the vacant space below the porphyry line, with some allowances for undulating surface. These lateral gulches have also produced much placer gold, and have received the débris from some disintegrated cement deposits. Considering the richness of the Deadwood placers, it seems extremely likely that they have yielded much more gold than would have been produced from the concentrations of the more recently disintegrated vein matter. Cement gold ore, such as I have described, is remarkably well adapted for stamp-mill treatment. The gold amalgamates readily, and yields an amalgam which retorts from fifty to sixty per cent. of bullion, or nearly twice the usual amount. I have saved in an ordinary mill, not by any means satisfactorily arranged, from 89 to 93 per cent. of the gold content, as shown by a comparison of a tailings sample taken every few hours, with the total bullion return. In connection with a recent experiment in which hammered gold showed a repulsion to mercury, it has been remarked that the stamp-mill may make a loss of gold through this cause. In cleaning up the mortars after milling cement ore I have obtained hundreds of flattened grains of gold, but have never seen one that was not amalgamated upon the surfaces flattened by the action of the stamps.

If we now endeavor to group together the facts noted above, it does not seem a difficult undertaking to form a history which shall

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give a rational account of the successive geological changes which took place. First we have the proof that the gold veins and the contained gold were in existence, in much their present condition, prior to the Potsdam period. Then we have the Potsdam seas washing away the débris resulting from the disintegration of the quartz veins, and depositing it in deeper water, in accordance with its various specific gravities. At the same time the gradual wave action carried the gold to the bed rock in the same manner as it is settled in a miner's pan. The Homestake vein, by reason of its greater durability, formed a reef or low island, which never became deeply submerged. After a time these sediments became insular, and as such remained undisturbed, gradually becoming cemented into rock, until the recent eruptions of porphyry took place, causing intense local metamorphic action. The gold, which up to this time had suffered perhaps a loss in silver only, now became itself partially dissolved where the solvents were sufficiently powerful, and was again, at least partially, precipitated as thin films in the schists below.

Once more a period of rest occupied the time, until the erosive action of fresh-water streams cut through the upper strata and began to disintegrate the matrix of the gold, and afforded material for a new concentrating process. Disintegration and concentration have been going on until now, when the hand of man has hastened the work of nature.

This gold from the conglomerate, which found its way down the slopes to the gradually lowering bottom of Deadwood Gulch, was joined with new supplies brought from the Homestake vein through lateral gulches, and the result was the great Deadwood placer. That in Blocktail Gulch, however, received no new accession, and remained a placer which had received its gold entirely from the Potsdam sediment.

The gold that I have described as being precipitated with the cement gold does not occur in sufficient quantity to be of importance; but several miles distant gold occurs in the same formation in considerable quantity, and with such characteristics as to justify its being classed as a chemical constituent.

This locality is known as Bald Mountain, and comprises an elevated area of several square miles, through which quite an extensive mineralization has taken place. The same geological features are here met with that I have already described; a base of schists, upon which are typical quartzites, from which the sedimentary character has been almost obliterated by metamorphic action. These are

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penetrated in every direction by porphyritic dikes, the overflow of which has, in places, formed high peaks. There is generally a small stratum of conglomerate next to the schist, but the sediments were generally quite fine. Through the area mentioned ores of gold and silver are quite common, although I do not know that their treatment has as yet proved to be a financial success. The ores seem to be impregnations, and not confined to veins with well-defined walls. In fact, true vein quartz is rare, and I am not sure that I have seen any, although some of the quartzite would be taken for quartz if examined without a knowledge of its occurrence. The silver occurs as chloride, more rarely native, and is confined to the small fissures through the rock. Copper stain is also common. Gold occurs native, but in so fine a state as to be seldom visible. I have noticed it as a brown sponge in cavities in the quartzite, and with no metallic appearance until compressed with a knife, when it immediately assumed the lustre and color of gold. These cavities are very common in the quartzite, and are generally lined with small quartz crystals.

The ratio of gold to silver is variable, and ranges from a small percentage of the total value to half. Continuous bodies of rich ore seem to be rare, although specimens giving high assays can easily be obtained. From its appearance the sponge gold described should be nearly pure, but I have never been able to test it. At the time of my observations, which was several years ago, the developments through this region were very limited, and I was unable to form conclusive opinions regarding the character of these deposits. Certain facts seemed to be pointed out: First, that the metallic constituents seemed to be segregated along certain horizontal strata, through which there seemed to have been less resistance to the passage of the mineral solutions; secondly, that in these planes there is a concentration along certain vertical planes, which planes are the contacts of the quartzite with porphyry dikes. Almost all of the openings showing ore conform in a degree to these two conditions. I have sampled portions of decomposed porphyry which were very rich in silver, and gold or silver seemed to be found in almost every opening made along a certain plane within certain limits. I have also examined these dikes below the contact of the quartzite and schist, and found them, to a certain extent, lines of mineral segregation. It therefore seems doubtful whether the metals came from below, or were derived by segregation from the sediments themselves. I am inclined to think that both causes were in operation. In one place we found that the lower sedimentary stratum was highly charged with oxide of iron, and that

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a sample gave over twenty dollars in gold per ton, although it was so fine that no gold could be obtained in the pan, an almost universal characteristic of these ores, and one which bars the use of the simple stamp-mill without amalgamating pans for reduction.

In other portions of the Hills argentiferous lead ores have been mined successfully from these quartzites, and present interesting features which do not properly come within the scope of this paper. The mineralizations of this character are probably of the age of the porphyry eruptions, and from a scientific standpoint are exceedingly interesting. The subject is one needing much more attention than I have been able to give; and as a reason for the lack of information upon many points treated of in this paper, I can only say that the facts I have presented were not obtained in the course of a systematic investigation, but incidentally while engaged in constant professional work.

SOME PECULIARITIES IN THE OCCURRENCE OF GOLD IN NORTH CAROLINA.

BY PROF. W. C. KERR, STATE GEOLOGIST, RALEIGH, N. C.

THE distribution of gold is obviously much wider than is commonly supposed. Besides the usual matrices, vehicles, or associates, such as quartz, pyrite, chalcopyrite, etc., I find it occurring in quite a range of common rocks. For example, at the Rhodes mine, in Gaston County, a body of 9 to 12 feet of decomposed, light-gray gneiss was worked together with the strings of quartz, and yielded from six to ten dollars to the ton.

A mine in Moore County yields its gold mainly from a feldspathic schist.

In the famous King's Mountain mine, in Gaston County, the gold is obtained not only from the seams of quartz in a blue, hydromicaceous schist, but a 60-foot ledge of grayish-blue, fine-grained, schistose limestone is quarried out bodily and sent to the stamps. It is gold-bearing throughout.

In Montgomery County the singular concretionary, conglomeritic, quartzite schist, which contains Emmons's *palæotrochis*, is gold-bearing over wide tracts of country. This fact was noticed by Dr. Emmons. But a still more striking and significant fact is, that a large part of the gold of Montgomery, Davidson, and Randolph counties,

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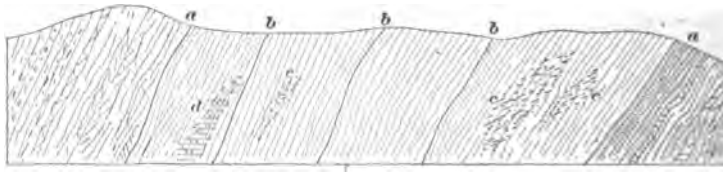
on the waters of the Yadkin and Uharie rivers, is contained in ledges of thin-bedded quartz slates, often pyrophyllitic or feldspathic, and frequently scaly and micaceous.

The range of noted mines extending twenty miles northward from near the mouth of the Uharie River, including the Russell, Beck, Laughlin, Jones, and others, come under the description just given. These slates, shales, or schists, stand almost vertical, and are generally decomposed to a considerable depth, 20, 40, or 50 feet, and are excavated *en masse*, generally with pick and shovel, sometimes through a cross-section of several hundred feet in length, and the whole mass is carried through the stamp-mill and rocker.

The accompanying diagram represents the last-named mine in cross-section. It is simply an open cut in the side of a hill, 50 to 70



feet high, formed by a ravine which has cut across the strike of the formation. The workable strata, between *a* and *a*, differ imperceptibly from the bounding rocks, and they pass insensibly into each other, the outside strata becoming gradually more heavily bedded, hard, and quartzose. Within the worked area there are lean strata, that are harder and thicker, and more quartzose or chloritic, as at *b*, *b*, *b*. At *d* a portion of the strata is charged with a fine-grained pyrite, that sometimes constitutes a large percentage of the rock for 2 or 3 feet in thickness. At *c*, *c*, *c*, portions of the strata are crusted with ferruginous scales and limonite, resulting from the decomposition of pyritous masses of slate. This mine may be taken as a type of an extensive zone of mines, that extends even beyond the Yadkin and into South Carolina, including the well-known Brewer mine.

Within a few months past I have found that the gray, much-jointed quartzites and felsites of the Huronian hills on the eastern side of the great slate belt, carry a workable percentage of gold through masses of great extent.

Gold has also been found by Mr. Hanna, of the Charlotte mint, in a trap-dike that is to be seen in that vicinity.

From the facts here given, it would seem that gold is so widely diffused that we may expect to find it in any kind of rock.

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THE CRYSTALLINE ROCKS OF VIRGINIA COMPARED WITH THOSE OF NEW ENGLAND.

BY PROF. C. H. HITCHCOCK, STATE GEOLOGIST, HANOVER, N. H.

A BRIEF residence in Virginia has enabled me to examine some of its crystalline strata, and a few hints, concerning their correspondence with similar rocks elsewhere, may be of service to those who are studying them.

In comparing the crystalline rocks of Virginia and New England, we may first recall the similarity of their geographical position. They constitute a continuous belt, being traceable through the Highlands of New York and New Jersey, Southeastern Pennsylvania, in the counties of Bucks, Montgomery, Philadelphia, Delaware, and Chester, and Maryland. Thus the Green Mountains of Vermont and the White Mountains of New Hampshire seem to be topographically continuous with the Blue Ridge and Midland districts of Virginia. This tract of country has been termed the *Atlantic* area in distinction from the *Appalachian* territory, whose eastern limit is the great Lower Silurian limestone valley extending from the St. Lawrence and Champlain valleys to Alabama. The Appalachian formations were studied by the brothers Rogers, forty years since, and found to rest unconformably upon the western flank of the Blue Ridge, the oldest of the series adjoining the gneisses, followed westerly by the other Palæozoic members in a regular ascending order, to which numerical designations were applied—Number 1 being the Cambrian, Number 2 the Lower Silurian limestones, etc. In Vermont the same conclusion was presented in the State reports: the Green Mountains were said to possess the anticlinal structure, and to underlie the quartzites and limestones. Inasmuch as this Atlantic area is topographically continuous from the Middle to the Northern States, and is unconformably overlaid upon the west side by the same succession of strata, the presumption is very strong that the history of both sections has been the same, and that the entire area is of Eozoic age.

Cross sections, in both districts, illustrate the existence of gigantic overturns, causing the strata of the Appalachian region to dip towards the Atlantic gneisses. To the beginner it would appear that the Silurian groups must dip beneath the crystallines, and hence many of the geologists in the beginning of the study of the stratigraphy of this eastern border of the continent believed that

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the Atlantic gneisses were newer than Eozoic. Only those who have worked in this crystalline region can appreciate the magnitude of the obstacles presented by the well-nigh universal prevalence of erroneous views. For thirty years an exaggeration of the metamorphic theory spread like a blight over the study of the older rocks. We now understand, both in Vermont and Virginia, that the Potsdam quartzites are newer than the crystalline gneisses to the east of them, both because the fragments of the former have been derived from the disintegration of the latter, and because the discordances of stratification, exhibited at Sunderland, Vermont, and Balcony Falls, in Virginia, cannot be otherwise explained. Though long an opponent of this view, Professor Dana now accepts the doctrine of the greater antiquity of the Green Mountain gneisses, when compared with the Potsdam quartzites on their western flank.

While the sequence of the Palæozoic column has been satisfactorily worked out in Virginia, little attention has been paid to the order of the crystalline series. First of all, it became clear that Logan's suggestion of the separation of the Eozoic into Laurentian and Huronian was applicable to the east. This was admitted by H. D. Rogers in 1858, using the terms Hypozoic and Azoic, instead of the geographical terminology. We can now subdivide these groups still further. The proposed institution of a Labrador or Norian system fails, because the rocks, thus distinguished, are of eruptive origin. In New Hampshire we find at least four well-marked subdivisions of the older series; (1), porphyritic gneiss, (2) protogene or "Bethlehem" gneiss, (3), ordinary or Lake Winnipiseogee gneiss, and (4), the Montalban. In the absence of detailed studies of the typical Laurentian areas it is impossible to know whether similar divisions can be recognized in them. From imperfect data we have concluded that the oldest, and possibly the first three, of the New England groups represent the Laurentian of New York and Canada. The Montalban is more evidently an independent system.

The Green Mountain gneisses are related to the second and third of the New Hampshire series. They are repeated by folds in Southern Vermont, and overlie the porphyritic gneisses along the western border of New Hampshire, in the Connecticut Valley—the older system lying east of the newer one. The same order is perceived along the James River Valley, in Virginia. At Balcony Falls and further east, the gneisses are like those of the Green Mountains. Where the Tobacco Row range has been cut through, the porphyritic gneisses show themselves, though not abundantly. Between

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these ridges an argillitic schist shows itself, which Professor Campbell regards as a part of the Laurentian. As this kind of rock has not usually shown itself so early, I would raise the question whether it will not be found to lie in a synclinal trough—possibly inverted—upon the gneisses, and to be of Huronian or Cambrian age.

This porphyritic rock is not seen in the next section of the Blue Ridge, along the Norfolk and Western Railroad, to the southwest of Lynchburg. Near the dividing ridge the Peaks of Otter show themselves conspicuously. These so closely resemble some of the New England eruptive granite cones as to suggest a like composition and origin. Quite near them on the railroad I observed a coarse syenite, which may possibly be connected with their mass.

The Huronian seems to occur in long narrow strips, inclosed by the gneisses, and possessing a complex synclinal structure. Where the strata are monoclinal they should be regarded as an overturn synclinal. Typical schists of this system, with the included minerals, are repeatedly described in Rogers's reports. At first it was thought that only the "talcose," or soft greenish hydro-mica schist with the steatite and serpentine should be referred to this system. But later studies and comparisons make it necessary to add great developments of argillitic quartzites and mica schist, as well as diabases and protogenes, to the softer schists both in New England and Virginia. This step will relieve the otherwise excessive reference to the Cambrian of many unfossiliferous terranes. In New England the softer schists are rarely found east of the Connecticut-Merrimack water shed. A similar area is that which is crossed by the Virginia Midland Railroad east of Manassas, and to the southwest of Charlottesville. The same or similar rocks are traversed along the Norfolk and Western Railroad, between Lynchburg and Thaxton's Station. It is also largely developed east of Lynchburg, along the Richmond and Allegheny Railroad.

Another rock, more suggestive of Huronian than any other Eozoic or Palæozoic affinities, occupies the south part of Montgomery County in the gold-region of Brush Creek, skirting Pilot Mountain—the western fork of the Blue Ridge. The rocks are coarse protogenes, cut by large auriferous quartz veins. It is certainly three or four miles wide, with a less dip to the east than the Cambrian quartzite of Pilot Mountain. My explorations did not extend far enough to the east to explore the gneissic rocks of the plateau, which are, probably, Montalban, and connected with the lofty Black Mountains of Western North Carolina.

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Between Pilot Mountain and Christiansburgh a great thickness of slates and sparry limestones is exposed, which correspond very closely to the Taconic system of Emmons, as developed in Eastern New York and Western Vermont. They were referred to formation No. 1 by W. B. Rogers.

It would seem probable that the broad Huronian belt between Washington and Harper's Ferry, on the Potomac, which continues southwesterly past the James River, according to Professor Fontaine, will still be found to occupy the ground all the way to North Carolina. As the Blue Ridge divides near Roanoke, and the branches extend through North Carolina into Georgia, it will be interesting to know whether the Huronian accompanies the Cambrian slates and quartzites. Inasmuch as copper and gold follow these ranges, the solution of the problem will have important practical bearings, and will also show whether the Montalban is inferior to or superior to the Huronian. Large Laurentian areas may be looked for in the midland Virginia district.

SOME DRIFT HEMATITE DEPOSITS IN EAST TENNESSEE.

BY EDWARD NICHOLS, RIDGE VALLEY, GA.

THESE deposits, which are found in James County, Tennessee, differ both in their mode of occurrence and in their chemical constitution from any other ores belonging to the same geological horizon which are known to the writer. Taylor's Ridge, or White Oak Mountain, is a long monoclinal ridge, which starts from a point near the Tennessee River in Meigs County, and, following a southwest course, extends unbrokenly into Cherokee County, Alabama, where it finally disappears. It is made up of strata of the Upper Silurian rocks, which dip to the southeast. To the eastward of this ridge, which is generally several hundred feet high, are a series of low foothills or knobs, composed of Clinton shales carrying seams of fossiliferous hematites. In the neighborhood of the East Tennessee, Virginia, and Georgia Railroad, where it crosses the ridges, considerable ore has been mined from these seams during the past ten years. Most of the workings have been superficial, and the ores mined, with one exception, carry a silicious and non-calcareous gangue, and contain from fifty to sixty per cent. of iron.

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In this neighborhood there are three parallel ranges in which these seams of ore are found, the distance between them being about half a mile. While the geological structure of each of these series is no doubt identical there is a surprising difference in the quality of the ores found in them.

Lying on the eastern slope of the foot hill nearest Taylor's Ridge are the deposits to which attention is here particularly called. Two closely parallel seams of ore, whose character is shown in analyses III and IV, given below, are found outcropping near the summit of the same hill. The ore at the base shows itself at the surface in irregular patches in the form of well-rounded gravel and small boulders. The underlying soil, which is a ferruginous clay, has similar ore mixed through it to a depth of from six to eight feet, and it is in sufficient quantity to be profitably worked. In appearance this ore has a reddish-black color and its structure is quite dense and apparently impervious to the action of meteoric solvents.

Its chemical condition is, however, such that it is difficult to connect it with any of the neighboring fossiliferous seams from whence it is likely to have been derived. The following are analyses of the gravel ore and of the neighboring ore seams:

Number of Sample.	Phosphorus.	Silicious matter.	Metallic iron.
I, ...	0.075	11.35	59.05
II, ...	0.054	16.63	62.72
III, ...	0.395	23.40	54.54
IV, ...	0.399	16.15	53.69
V, ...	0.203	17.50	53.26
VI, ...	0.249	16.80	52.96

I and II are gravel ore; III, silicious ore from seam near I and II; IV and V are limestone ores from seam close to III. VI, ore from seam one mile west of the gravel ore.

From analyses I and II it will be seen that the distinguishing characteristic of this drift ore is its richness in iron and freedom from phosphorus, making it available for the manufacture of Bessemer iron. No record can be found of any Clinton fossiliferous ore containing as small an amount of phosphorus in proportion to the iron.

Analyses III, IV, V, and VI, show so much more phosphorus in proportion to the percentage of iron that it seems improbable

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that this drift ore—for such it undoubtedly is—could have been derived from them.

Unfortunately the extent of these drift deposits seems quite limited, for they would be particularly valuable in this region, which is singularly deficient in rich Bessemer ores.

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*ON THE COMPARATIVE EFFICIENCY OF FANS AND POSITIVE BLOWERS.**

BY H. M. HOWE, A.M., M.E., BOSTON, MASS.

On commencing the construction of the Orford Company's copper smelting works, at Bergen Point, N. J., I endeavored to convince our President, Mr. W. E. C. Eustis, by actual tests, that at the pressure of from 15 to 18 ounces per square inch, employed by us in smelting, less power was consumed in delivering a unit of blast by a Baker blower than by a fan blower. I attempted to prove this in the following manner: Across the mouth of a No. 5½ Baker blower I firmly fastened a board with two round holes, 6 inches in diameter, cut in it. The board was fastened so tightly that no air could escape except through the holes. I then drove the blower at several different speeds, observing the pressure at which the air escaped through the two openings for each different speed of the blower, and also indicating the engine, whose only work at that time was to drive the blower.

From this I calculated the quantity of power required to deliver, with a Baker blower, sufficient air to keep the pressure at a given point, while it escaped freely through the two six-inch apertures into the open air; or, in other words, to deliver air at a given pressure through these two openings. From the total power so consumed it was, of course, necessary to deduct the power which was required to drive the engine itself. This was ascertained by removing from the engine the belt which drove the blower, and then noting the quantity of power consumed in simply turning the engine over without any

* When this paper was read it was stated that the writer hoped to add to it the results of further experiments on the Baker blower. Since then he has experimented on two almost new Baker blowers at Pelton, Arizona. The results so obtained merely strengthen the conclusions previously arrived at, and have, therefore, been incorporated in the paper, rendering it slightly fuller than when originally read.

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load, at the speed which it had when driving the blower. The remainder gave, approximately, the power consumed by the blower itself. I say approximately, because undoubtedly the engine consumed slightly more power in the mere act of turning itself over when driving the blower than when running without any load, since, in the former case, the engine shaft was, of course, heavily strained against its bearings by the tension of the blower-belt.

These tests were made on a new Baker blower at the maker's works.

I next applied the same tests to a small "G" Hawkins fan, which had been very roughly handled by unskilled mechanics, and had been strained by being driven at a speed and pressure for which it was not calculated. To my great surprise, on comparing the results, the little Hawkins fan had actually required less power to do the same work than the Baker blower.

The results of these tests are represented graphically by the lines on the accompanying chart, in which horizontal distances from the origin represent the pressure of the blast, and vertical distances the power consumed in delivering it. Each of the lines represents the results of tests made on one blower, and with a fixed number and size of orifices. These lines, to repeat, indicate, by the distance of any particular point on them from the line *O X*, the pressure obtained at any one observation, and, by its distance from the line *O Y*, the power consumed in delivering the blast, at that pressure, through one six-inch round opening. Although in the tests from one to six such openings were used, the results are all reduced to the power consumed per one six-inch opening to facilitate comparison. The number of openings employed was the same for all the observations which are represented by any one line. The line at the bottom of the chart shows the results obtained with the "G" Hawkins fan, and the line next above it gives those of the Baker blower. There is a fairly uniform margin in favor of the Hawkins amounting to some ten per cent.

The lines at the left hand of the diagram give the results obtained with two No. 4½ Baker blowers at the Pima Copper Mining and Smelting Company's works, at Pelton, Arizona. One of these (slightly the least efficient of the two) had been used only some three hundred hours, and was apparently in good condition. There seemed to be an excellent fit between the parts, and I am at a loss to account for the very low efficiency of the machine. At the highest speed considered safe by its makers, it could only raise the pressure of the

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air escaping through a 6-inch round aperture, to 5 oz. The other Baker blower at the same works, though consuming slightly less power, was unable to raise the blast escaping through a 6-inch round aperture above a pressure of 5 oz., at nearly the highest safe speed (184 revolutions).

It will be observed that (as with the No. 10 Sturtevant fan), the consumption of power, per unit of aperture for a given pressure, is slightly higher with a small aperture than with a larger one, the line giving the results obtained with a 3-inch round orifice being uniformly a little higher than that showing the results obtained with one 6 inches in diameter.

Let us now examine the four lines, exhibiting the results obtained with a No. 10 Sturtevant fan blower. The upper line shows the consumption of power by this blower per six-inch opening at various pressures when the fan delivered air through only one such opening; the next line shows similar results when delivering air through two such openings, the next the results with three openings, and the lowest with six.

Here the consumption of power, per unit of air delivered, is much less when the fan delivers a large volume of air, than when it delivers a smaller volume. Thus we find that, for the same pressure, the consumption of power is nearly twice as large per unit of opening, when only one opening is employed, as when there are three openings. It therefore appears to be more economical of power, to work this fan well up to its normal capacity, than to run it much below its capacity. This is probably the reason why the little Hawkins fan shows such high efficiency, as it was driven much nearer to its maximum capacity than the other fans were.

The speed of the engine, and therefore the speed of the fan, was almost exactly the same in the tests of the No. 10 Sturtevant fan for a given pressure of blast, whether one, two, or three openings were employed. Observations were made also with four and five openings, with results parallel with those here recorded.

The observations of the No. 10 Sturtevant fan were all made in triplicate, with very closely agreeing results. In some instances there was a discrepancy of less than 0.1 per cent. between the different observations.

Comparing these results with those obtained with the two No. 4½ Baker blowers, it will be observed that the capacity of the fan greatly exceeds that of its rival, as regards volume, and as regards pressure when any considerable volume is delivered; as for efficiency, the

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consumption of power per unit of opening is uniformly about five times as great for a given pressure with the Baker blower, as with the fan, when the latter is working anywhere near its normal capacity. Even when this fan is delivering but a small fraction of its normal capacity (the air escaping through a single 6-inch orifice) its consumption of power, per unit of work, is considerably less than one half of that of either of the No. 4½ Bakers, for any of the pressures observed above 6 oz., and at lower pressures only slightly above one-half.

The No. 10 Sturtevant easily fills five times as large an orifice at 16 oz., and four times as large an orifice at 15 oz. pressure, as either of the No. 4½ Bakers does at 5 oz., the cost of the former machine being about one-third of that of the latter.

At the heads of the two arrows are given the results obtained with a No. 9 Sturtevant fan. The upper arrow shows the consumption of power when delivering air through one opening; the lower arrow, the consumption per opening when delivering through two openings. The difference between the consumption of power per opening for one and for two openings is much less for this fan than with the No. 10 Sturtevant.

Another line shows the results obtained with a No. ¼ Root blower at the Massachusetts Institute of Technology. The observations on this blower (as well as on the several Baker blowers and the "G" Hawkins fan) were made with a mercury pressure-gauge, of the ordinary U form, which does not admit of close readings. This probably accounts for the sharp bend in the middle of the line. The observations on the No. 10 Sturtevant fan were made with a water-gauge, U shaped, which permits a very much closer reading. Accordingly, we find the lines, which record these observations, much more nearly straight. One of them would be made perfectly straight by an alteration of about $\frac{1}{5}$-ounce in one observation, and $\frac{3}{10}$-ounce in another, or by a difference of ½ horse-power in the two discordant readings. Considering to what extent the conditions necessarily varied during the trials, these results come as near to a straight line as can be expected.

The No. ¼ Root blower had not been used very much; it is only occasionally employed, when the little experimental furnace, which it supplies, is used. It is in a rather favorable position, and in careful hands; yet, the results of these tests, which were made in triplicate, show that it consumes from two to three times as much power as some other blowers.

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The black dot, inclosed in a circle, shows the consumption of power by an experimental fan blower, which is nearly three times as great as that of the "G" Hawkins.

Let us now consider some of the advantages and disadvantages of these two classes of blowers,—fans and positive blowers. In first cost, the fan has very greatly the advantage. I should say, roughly, that, for the same capacity, the Baker blower costs about four times as much as a fan. In the cost of repairs, the Baker, probably, has a slight advantage over fans, as ordinarily used, the wear and tear of the belts being quite expensive. But I do not think this is at all necessary. At Bergen Point we have delivered as much as 100 horse-power to one fan, and we hardly ever have any trouble with the belt. Makers of fans have paid great attention to getting smooth-running bearings, but, until very lately, they have always, as far as I know, put on ridiculously small pulleys, both as regards diameter and width. The consequence is, that the belts are generally overstrained, last but a short while, and break at inconvenient times.

If the width and diameter of fan pulleys were both doubled, and one good broad belt were used, the wear and tear would be insignificant. Our experience has been, that one broad belt lasts much longer than two slightly narrower ones, and I should never think of having a fan run with two belts. Again, belts should be made continuous. When running at a speed of 1¼ miles per minute, as our fan-belt does, and transmitting a heavy strain, I do not believe that lacing, hooks, or any similar kind of fastening, can be made to stand the blow which it receives when it strikes the driven-pulley. To wear well, the belts should be made in one continuous piece.

Undoubtedly, much power is consumed in overcoming the centrifugal force of the belt at such a high speed, and in so rapidly changing its direction. Mr. Eustis has proposed to overcome this objection to the use of fans by driving them by means of a small turbine wheel attached directly to the shaft of the fan itself, and driven by a plunger pump actuated by the engine.

A good Sturtevant or Hawkins fan, with decent treatment, appears to last almost indefinitely, and to work as efficiently when old as when new. I should think, from its construction, that the consumption of power by the Baker blower would increase with its use. The efficiency of the blower depends mainly on having an accurate fit between the central bladed cylinder and the two revolving crescents. Now, when the machine is new, there is certainly a most excellent fit; indeed, the whole workmanship of the blower leaves

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nothing to be desired. But it seems to me that when the bearings of the crescents wear, as wear they must in time, in spite of their great breadth, there will be a tendency on their part to separate from the cylinder, and, by allowing the air to slip back through the slit thus formed, to greatly decrease the efficiency of the machine. In careful hands, this wearing of the bearing of the crescents can be taken up; but in how many smelting works would it actually be taken up?

The fan needs more careful and consequently more costly attendance than the Baker blower. It must be well oiled, and with the very best of oil, and the belt must be kept in the very best possible condition. The necessity of this more careful handling for fans is in great part due to the high speed at which they must run. In remote places, where the best of belting and the fine and costly oils, necessitated by the high speed of fans, are difficult to get, and where the somewhat more skilful labor they require is costly, this is certainly a serious objection.

On the other hand while a Baker blower may be kept running by a man not sufficiently careful and intelligent to keep a fan from getting very seriously out of order, or even from becoming entirely disabled, yet I am inclined to think that considerably more skill and intelligence is required to keep a Baker blower up to its highest efficiency than so to maintain a fan. Almost the only things necessary to enable a fan to work most efficiently are to keep its bearings thoroughly lubricated and its belt in good order. This must also be done with the Baker blower; but in addition the position of its moving parts must be regulated with the very greatest nicety, to obtain its best efficiency (though, indeed, it can be kept running, but most inefficiently, if this be neglected), and I believe that this adjustment requires much higher intelligence and care than are needed for the proper maintenance of a fan.

On seeing the large engines at the Orford Company's works, it has been remarked that the fact that we used so much more engine-power per furnace for our fans than was consumed in Western smelting works, where the Baker blower is in general use, showed that fans were the less efficient of the two. A little reflection shows that this is no proof, there being great differences in the conditions. In the Western smelting works, using the Baker blower, they do not smelt more than 50 tons of mine per twenty-four hours, in furnaces of the same size as those in which we smelt from 90 to 100 tons. They use very small tuyeres, and in general a low pressure,

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and consequently a very small volume of air. We use very large tuyeres, and a high pressure. From frequent comparisons, I do not think that we are using more power per unit of air delivered, though we unquestionably use much more per furnace, and probably more per unit of mine smelted. Any slight excess of consumption of power per unit of mine is much more than counterbalanced by the great saving of labor effected by smelting, as we do, nearly double the amount of mine per furnace.

Again, it would probably be impossible to run brick furnaces as we do for many months at a time, without water tuyeres or any protection for the brickwork, and with highly basic and corrosive slags, if we did not employ enormous volumes of air at a high pressure. This at the same time wholly prevents the formation of salamanders. Without this excess of air, and with our highly ferruginous slags, salamanders would inevitably form.

These facts and considerations, while not sufficiently extended to establish, yet point towards the following conclusions:

1. Fans and Baker blowers work more efficiently at a given pressure when delivering large volumes (*i. e.*, when working nearly up to their maximum capacity) than when delivering comparatively small volumes. Therefore, when great variations in the quantity and pressure of blast required are liable to arise, the highest efficiency would be obtained by having a number of blowers, always driving them up to their full capacity, and regulating the amount of blast by altering the number of blowers at work, instead of having one or two very large blowers and regulating the amount of blast by the speed of the blowers. On the other hand, this arrangement will often be a costly one, since, if fans are used, a separate pipe for each blower would probably be necessary.

2. There appears to be little difference between the efficiency of fans and of Baker blowers when each works under favorable conditions as regards quantity of work, and when each is in good order. But even new Baker blowers, when apparently properly handled, seem liable to get into a state in which they require, even when performing the most favorable quantity of work, much more power than a fan does when working at its normal capacity, and even twice as much as a fan requires when working at say one-sixth of its normal capacity. The fact that none of the fans experimented on showed any such abnormal consumption of power, goes to show that their efficiency is not so liable to such extreme and astonishing degeneration.

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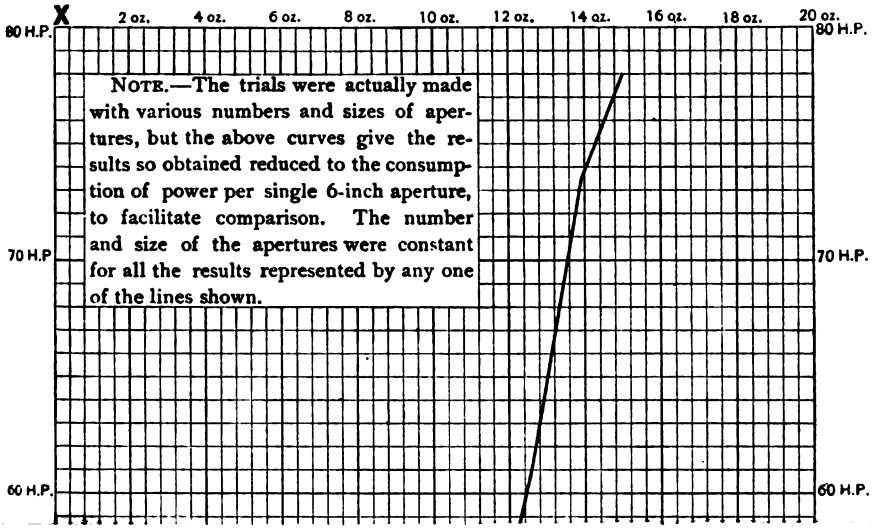

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This is probably due to the fact that almost the only thing which lowers the efficiency of a well-made fan on a normal amount of work is faulty lubrication, which quickly makes itself known by the heating of the journals; while the efficiency of the Baker blower depends not only on the lubrication, but more especially on an accurate adjustment of the moving parts, and there seems to be no ready way of detecting even a serious inaccuracy in this adjustment.

3. While a degree of stupidity and carelessness on the part of the attendant, which would damage or even disable a fan, might merely lower the efficiency of a Baker blower, yet, to insure a high degree of efficiency, more skill and care in the attendance are required by a Baker blower than by a fan.

4. The cost of positive blowers is about four times as great as that of fan blowers having the same capacity at the pressures experimented on (from two to twenty ounces).

5. The cost of repairs, insignificant for either class of blower, if properly designed and cared for, is slightly greater for fans than for Baker blowers.

6. The general impression that, by using Baker blowers, a higher blast pressure is obtained in foundry and cupola smelting works than can be produced by a fan is incorrect. An enormous volume of air (sufficient to fill fourteen 6-inch tuyeres delivering into an open-burdened coke furnace), at a pressure of twenty ounces per square inch, is easily delivered by a single fan. The writer is not aware that any cupola practice on this continent requires a higher pressure.

7. The experiments on the Root blower tend to justify a general disfavor into which this machine has fallen, due to the apparently inevitably bad adjustment of the moving parts.

8. In adopting the general practice in the West of discarding fans in favor of Baker blowers, I believe that smelters have to a great extent blindly followed each other's lead, and that the general disfavor into which fans have there fallen is not justified.

9. For a given speed of fan, any diminution in the size of the blast orifice decreases the consumption of power and at the same time raises the pressure of the blast; but it increases the consumption of power per unit of orifice for a given pressure of blast. When the orifice has been reduced to the maximum normal size for any given fan, further diminishing it causes but slight elevation of the blast pressure; and, when the orifice becomes comparatively small, further diminishing it causes no sensible elevation of the blast

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pressure, which remains practically constant, even when the orifice is entirely closed.

10. Many of the failures of fans have been due to too low speed, to too small pulleys, to improper fastening of belts, or to the belts being too nearly vertical, in brief, to bad mechanical arrangement, rather than to inherent defects in the principles of the machine.

11. If several fans are used, it is probably essential to high efficiency to provide a separate blast-pipe for each (at least if the fans are of different size or speed), while any number of positive blowers may deliver into the same pipe without lowering their efficiency. In these cases, the higher cost of blast-pipe required by a group of fans would generally be much more than counterbalanced by the low cost of the fans themselves, as compared with positive blowers.

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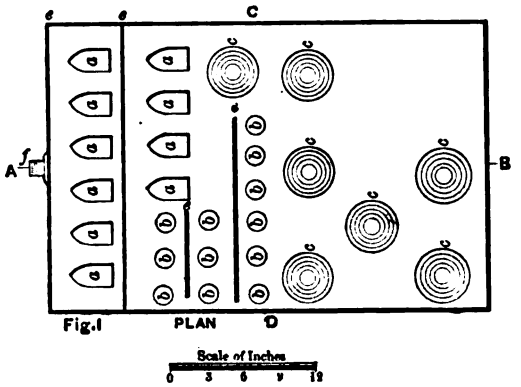
*ASSAYING OF SILVER BULLION.**

BY F. C. BLAKE, MANSFIELD VALLEY, PA.

THE apparatus which I shall describe in this paper has been in use for some time at the laboratory of the Pennsylvania Lead Company's works, and has been found to give good results, and to be simple and convenient.

STEAM BATH.—This steam bath is shown by Figs. 1, 2, 3, and 4. It is made of sheet copper, about one-twelfth of an inch thick,



the joints being brazed, and is used for heating the bottles in which the silver samples are dissolved, previous to the fineness determina-

* Read at the Harrisburg Meeting, October, 1881.

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tions by the Gay Lussac volumetric method; for heating the flasks in which the gold parting is made in bullion or other gold assay-buttons; and for general analytical work.

Fig. 1 shows a plan of the bath. The orifices, marked *a*, are made of the proper shape to hold the silver assay bottles in an inclined position, the necks resting on the raised flanges, *e e*. There is described in Percy's volume on *Gold and Silver*, Part I, page 289, a bath for heating silver assay bottles. It has this disadvantage, however, that the bottles stand erect, and there is a slight danger that some of the fine spray arising with the evolution of nitrous-oxide during solution of the silver may be projected from the bottle, or upon the stopper neck. When the bottles rest in an inclined position, there can be no loss in this way, though the stopper neck should always be washed down with distilled water before adding the salt solution. The orifices, marked *b*, are used for heating the small flasks, in which the gold is parted from silver buttons, the necks of the flasks resting on flanges, also marked *e e*. The ordinary one-ounce flasks we find to be more convenient for gold parting than the special long flasks called parting flasks, especially in transferring the

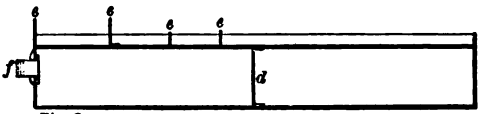

Fig.2 SECTION AT A B.

gold to the small porcelain crucibles in which it is annealed in the muffle furnace. The orifices, marked *c*, are used for heating beakers, flasks, etc.,—for general analytical work. They are covered by the

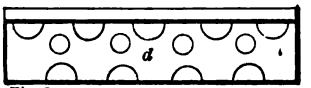

Fig.3 SECTION AT C D.

usual overlapping spun-copper rings. Covers are also used on the orifices for silver assay bottles and gold parting flasks.

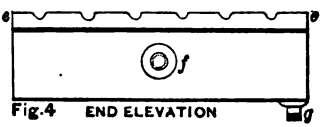

Fig.4 END ELEVATION

Figs. 2 and 3 show two cross-sections at right angles to each other. The flanges above referred to are shown at *e*; *f* is the inlet

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for steam ; *d* is a strengthening diaphragm. In Fig. 4, which represents an end elevation, *g* is the outlet for condensed water.

SHAKING ENGINE.—Fig. 5 gives an elevation of a small upright engine, which has a rod, *c*, running through the packing gland, *d*, in the upper cylinder head. A box, B, is screwed to the rod, *c*. This box is made to hold nine silver assay bottles. A piece of thick sheet rubber is fastened upon the bottom of the box, and also a sheet to the under side of the cover, *f*. The cover, *f*, is clamped down tightly

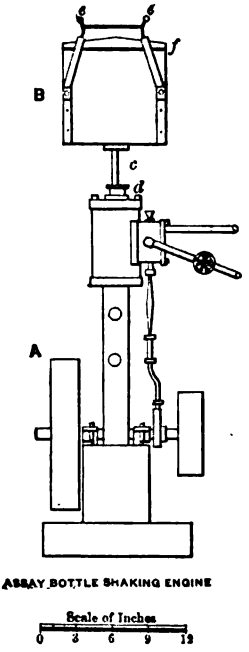

Fig.5

upon the bottles by the hinged holders, *e e*, which are held in place by a rubber band. In this way the bottles and their stoppers are held firmly in place, and will not be disturbed by the shaking. This small engine, as arranged for shaking the silver assay bottles, was introduced by Mr. E. F. Eurich, and has proved to be a great convenience in making silver fineness determinations by the Gay Lussac method. The bottles are excluded from the light, and there is no difficulty in obtaining a perfectly clear solution, when the bottles are shaken from one to two minutes. If more convenient, the small engine could be replaced by a crank, run from a line of shafting, but I think the engine to be preferable, and to be a great improvement

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over hand shaking, or the shaking case, as arranged with springs above and below the case.

We have found that the Gay Lussac method of volumetric assay is the most reliable and convenient for determining the silver fineness of bullion, that contains but a small percentage of copper or other impurities. The Stas pipette is the best form for convenience and accuracy. The arrangements for determining the temperature of the salt solution, when assays are made as described by Sire and others, are not reliable in general work, unless more time and care are used in making corrections than would be needed to make a determination upon fine silver of the value of the salt solution with each set of assays. This latter method is probably the better one. With each set of determinations one should be made upon pure silver, from which the strength—whether above or below the normal—of the salt solution can be determined. All the assays of any set, including that of fine silver, are made under exactly the same conditions, and the results should be accurate if the test silver is pure. There is no difficulty in preparing pure silver, if care is taken to obtain a pure chloride. If silver, 998 or 999 fine, cannot be used to dissolve for precipitation as chloride, it is best to redissolve the silver first reduced from the chloride and reprecipitate. The assays, made by different persons, of silver bullion bars, often do not agree exactly, especially when the bullion contains a considerable percentage of impurities. One cause for the different results is due to the sampling. The bar should always be sampled, when it is possible, as it is poured, a small portion being taken with a sample ladle, as soon before the bar chills as possible, and granulated in water. There will be sometimes a slight difference between the poured sample and one which is cut from the surface of the chilled bar, due to molecular changes in the alloy as the bar cools, especially if the bullion is quite impure and cools slowly. It is evident, I think, that a sample, properly taken when the bullion is poured from the cupel test, or from a crucible, is the sample which will most accurately represent the bar.

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*PRESENCE OF TELLURIUM IN COPPER.**

BY T. EGLESTON, PH.D., NEW YORK CITY.

SOME months ago samples of black oxide of copper and of pig copper from Colorado were sent to me to examine for arsenic and

* Read at the Harrisburg Meeting, October, 1881.

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antimony. I examined them both by the blow-pipe, and in the wet way, but found none.

A quantity of this material was purchased by a large metallurgical works, but when they attempted to refine it they pronounced it to be full of arsenic and antimony, so much so, that their furnaces were, as they said, "poisoned," and rendered unfit for refining. I then re-examined the samples, and at the same time some of the material which had "poisoned" the furnaces, and found no traces of arsenic or antimony when the usual amounts for analysis were used, but on taking very large amounts I found traces merely, in some parts of the sample, but not in all. As it was a matter of interest to ascertain what the white substance that "poisoned" the furnace was, I sent to the works making the black copper, and obtained some of the matte from which the black copper was made; I took careful samples, both of it and the black copper and the refined copper. I then found the impurity to be tellurium, a substance not heretofore known as occurring in copper. I give below one analysis of the matte, two of the black copper, and one of the refined copper:

	Matte.	Black Copper.		Refined Copper.
Copper,	55.02	97.120	98.090	99.705
Gold,	0.06	——	——	——
Silver,	0.40	0.132	0.128	0.135
Lead,	17.87	0.777	0.757	none.
Zinc and nickel,	2.22	0.070	0.100	0.024
Iron,	4.18	0.130	0.080	0.031
Sulphur,	20.02	0.236	*	trace.
Tellurium,	0.12	0.093	0.097	0.083
Arsenic,	*	0.006	*	0.091
Slag, etc.,	——	1.270	0.192	——
	99.89	99.834	99.444	100.069

* No traces were found with the blow-pipe.

The mattes and the black copper are results of the treatment of copper ores with the tellurium ores of Colorado. In the laboratory no traces of white fumes were shown on charcoal, but when the metal in the furnace was subjected to the process of "dry roasting," as was unintentionally done, very dense white fumes were given off. When refined and cast into cake, it had the ordinary appearance of cake copper. It was then reheated for rolling in the ordinary way, showing no signs of impurity. At the first pass in the rolls, very fine cracks showed themselves, which opened in succeeding passes. At a thickness of about 0.03 meter the cracks on either side nearly penetrated the cake, and at about 0.008 meter it began to fall to

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pieces. It was heated and rolled at different temperatures, but always with the same result.

When cold the metal is tough and malleable. Although the cakes in the moulds showed no coating, when they were heated repeatedly and allowed to cool in the air they became covered with a white powder, which proved to be the oxide of tellurium. The copper, as it comes from the cake moulds, has every appearance of being good copper.

This is the first time, so far as I know, that the presence of tellurium has been detected in commercial copper. But very little of it is removed in the treatment, as the four analyses show.

It is surprising how very small a quantity renders the copper red short, and consequently worthless for rolling.

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*HOT-BLAST STOVES AT THE EDGAR THOMSON FURNACES, "D" AND "E."**

BY JULIAN KENNEDY, BRADDOCK, PA.

WHEN it was decided to erect these furnaces the company also decided to use the Cowper type of stoves. It was, however, desirable to improve upon the plan of the stoves then in operation, to avoid, if possible, some defects which had shown themselves in them. The stoves now in use at Furnaces "A," "B," and "C" are of the well-known type of Cowper stove, having a circular combustion-chamber placed at one side of the stove, and a regenerator with crescent-shaped section, resting at the bottom on cast-iron gratings, which are supported in turn by cast-iron girders, the products of combustion passing up the chamber, down through the flues of the regenerator, and thence to the chimney.

The objection to this shape of stove, that the gases would not pass down the parts of regenerator lying beside and behind the combustion-chamber—the horns of the crescent, as it were,—did not apply to the newer form of stoves, with combustion-chamber having a straight wall next to the regenerator; but there were other defects, the principal ones being the small size of the openings through the regenerator and the material used for supporting it. The small passages ($4'' \times 4''$) soon choked up, and when a part of them became entirely closed, not only was the effective heating surface greatly diminished, but as the remaining openings were not sufficient to absorb the heat

* Read at the Harrisburg Meeting, October, 1881.

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fast enough, the products of combustion reached the bottom of the regenerator at too high a temperature, and caused the cast-iron gratings to crack and warp. The openings being very small and somewhat irregular, from the fact that they were built of tiles, set on edge, and each course free to get out of vertical alignment with the preceding one, it was very hard to clean them when choked, it being very often impossible to pass a chain through them without first driving through gas-pipe, the pipe being screwed together in short pieces as fast as driven down.

After careful consideration I decided, first, to adopt six inches as the smallest admissible size of openings; second, to abandon cast-iron supports for the regenerator; third, to use only one pass through the regenerator; fourth, to discharge gases from stoves and boilers into one common chimney; fifth, to use round instead of square openings through the regenerator.

It is, of course, desirable not to make openings any larger than is necessary, as the heating-surface is reduced by so doing. In fact our new stoves $21' \times 72'\ 6''$, with $6''$ openings, will have a little less heating-surface in the regenerator than the old stoves, $20' \times 56'$, with $4'' \times 4''$ openings. I have no doubt, however, that the effective heating-surface, after a few weeks' running, will be very much greater in the new stoves. One pass through the regenerator is better than three or more, provided the flues can be kept clean and the hot gases distributed evenly among them, for the reason that a larger area of openings is given and friction reduced, enabling more gas to be burned with a given chimney draught.

When the hot gases pass through a multiflue regenerator from top to bottom, the tendency is to cause an even distribution, for if one flue gets more than its share it becomes hotter than the others, and so has more of an upward draught, which tends to crowd the gases down the other and cooler flues. For the same reason the cold air entering the regenerator at the bottom has a tendency to ascend the hottest flues, so that when being heated and when being cooled the operation goes on very uniformly all over the regenerator. With openings large enough, even a very wide regenerator will work with the greatest uniformity, unless the passages to the chimney are badly proportioned, so as to allow the gases from one part of the regenerator to reach the chimney much easier than those from other parts.

The gases being discharged into the chimney at a temperature of 350° F., the draught is not very strong, but by also discharging the gases from boilers into the same chimney we get, say 40 per cent.,

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at 350°, and 60 per cent. at about 700°, which gives us a chimney temperature of, say 520°, thus greatly increasing the draught of the stoves. The boiler-draught is somewhat diminished, but this does not matter, as a draught strong enough for the stoves is far more than ample for the boilers.

Any one examining a dirty regenerator, with ordinary square openings, will observe that the most of the dirt accumulates in the corners. By making the openings round we get rid of the corners, and I feel confident that much less dirt will accumulate in the flues.

The stoves as built at Furnaces "D" and "E" are shown on the accompanying plates. The regenerator brick are hexagonal in section, ten inches across, and have holes six inches in diameter through them. In building we use, for first course, a row six inches deep, then one three inches deep, etc. We then use six-inch brick all through, until we reach the top, when the work is levelled up by using three-inch brick in every alternate row. By this means the joints between courses are broken and the openings kept perfectly true and straight from top to bottom. The regenerator is carried on firebrick entirely, no castings being used. The chimney is 16′ in diameter, inside, for 40′ up; then it tapers in to 15′, which diameter it retains to the top. The height from the point of entrance of the boiler-flue to the top is 235′.

From the bottom of the chimney nine-inch partition walls run up about thirty feet, giving nearly one-quarter of chimney to each battery of three stoves, and little over one-half to the boilers. From the top of these walls the gases, of course, have one common flue.

DISCUSSION.

MR. JOHN M. HARTMAN: When the Edgar Thomson Steel Works gave our firm orders to prepare the plans and specifications of the two twenty-foot furnaces, "B" and "C," they directed us to follow the designs of the Lucy Furnaces, at Pittsburgh, but allowed us to make any changes that would increase the output within certain limits. The largest volume of air blown in any twenty-foot-furnace up to that time was 15,500 cubic feet per minute. The "B" furnace was designed to use 18,500 feet of air per minute, and the stoves contained 92,000 square feet of heating-surface. After starting the "A" furnace and finding that the volume of blast used was greater than that originally intended, it was decided to increase the "C" stoves to 100,000 square feet of surface and use 20,000 feet

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of air, the "B" stoves having been finished by this time. After blowing-in "B" furnace, Mr. Kennedy found he could blow more than originally intended, and increased the volume up to 28,000 feet for maximum, which would require 140,000 square feet of surface. In spite of this excess of air the 92,000 feet of surface maintained 1050° in the blast.

When "C" furnace was in full operation, Mr. Kennedy used 30,000 feet of air per minute, and maintained 1050° with the escaping gas at the chimney at 350°.

To heat this enormous volume of air Mr. Kennedy was obliged to force the stoves with gas. As all the valves, regenerators, and chimneys were proportioned for 20,000 feet of air it required constant care to use the large volume of gas properly. This will explain the trouble he speaks of. The two new twenty-foot furnaces, "D" and "E," and that Mr. Kennedy is now building, have larger stoves, with better regenerators and chimneys, and I look forward to a production of 1500 tons weekly from each furnace.

NOTE.—November, 1882. The "D" and "E" furnaces have since produced 1825 tons.

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*AN IMPROVED MINING LAMP FOR ENGINEERS.**

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

THE accompanying diagrams represent a lamp provided with certain improvements which render it more serviceable for the use of the engineer or other mining official who is often compelled to visit several mines a day remote from each other, and may be called on to use the magnetic needle in any or all of them.

These requirements demand that the material of which it is made should be copper, and that it should be capable of being closed oil-tight, for emptying and refilling the lamp at each mine would be a less expeditious as well as a less cleanly process, and transporting a lamp of the ordinary kind over rough roads on horseback or in wagon, would result in spilling the greater part of its contents.

The general form of the lamp, including the false back to keep

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* Read at the Virginia Meeting, May, 1881.

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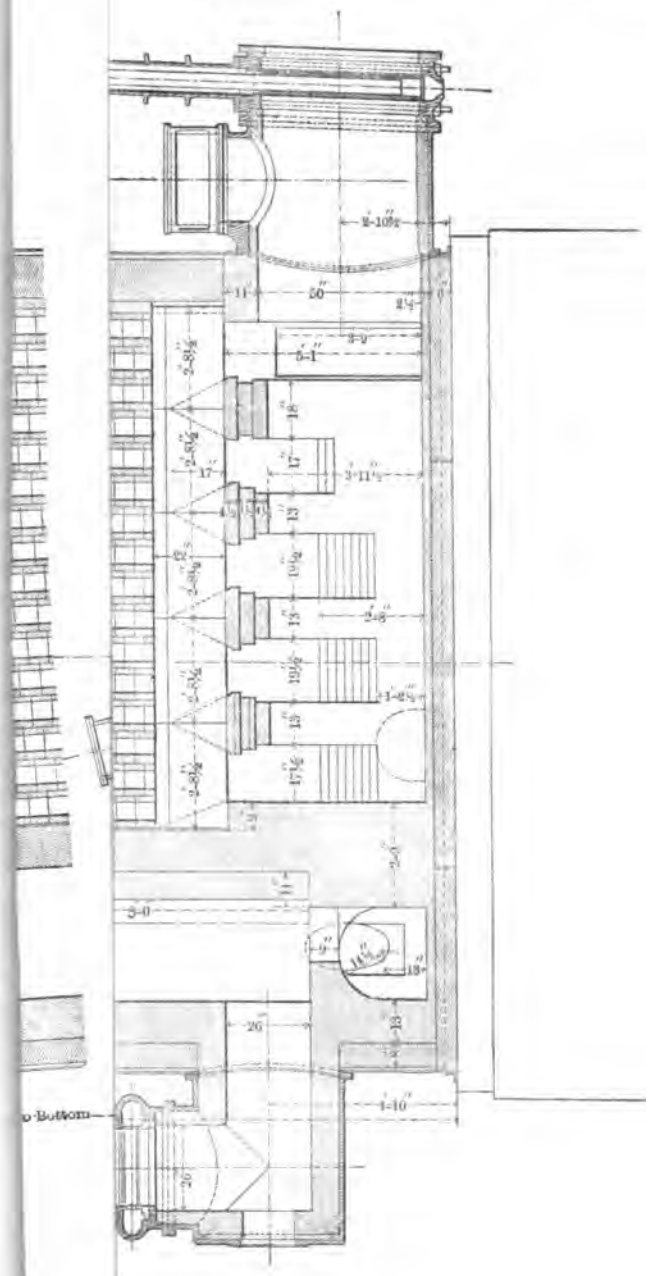

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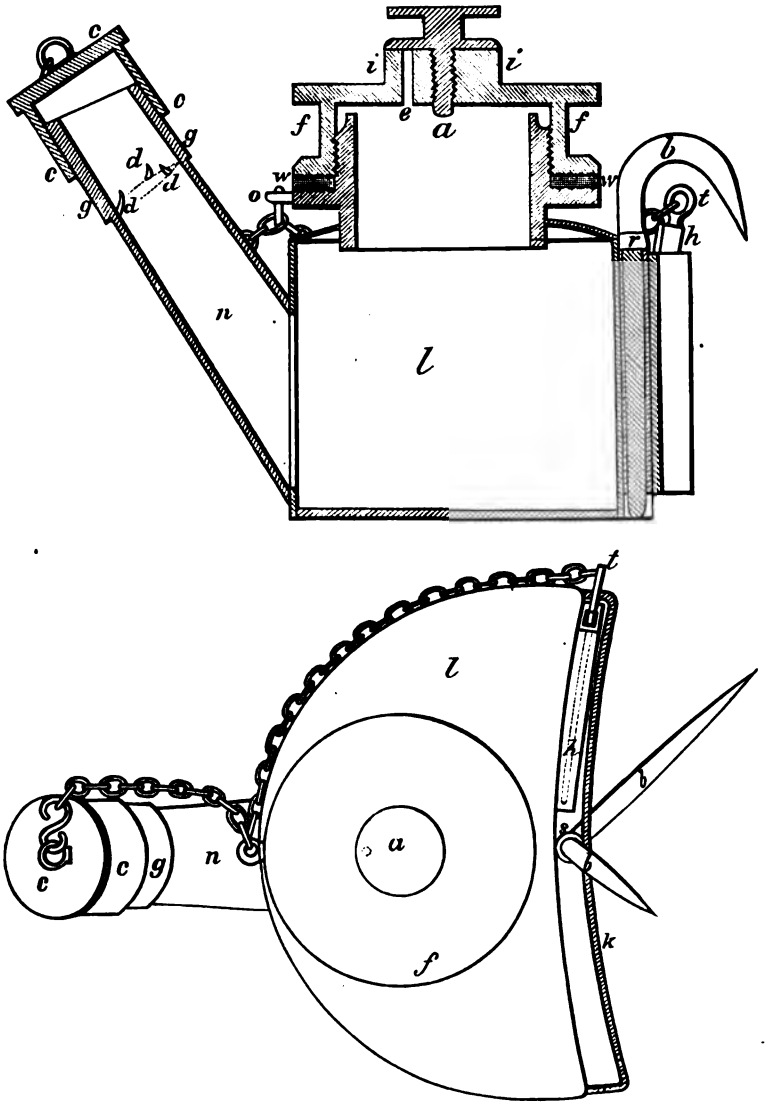
the heat from the head, is the same as that sold for some years by Heller and Brightly.



The following is a nearer description of its parts:

a. Screw, with milled head and flange, opening or closing

e. Air-vent.

c. Cap, fitting on *a*, which it surrounds loosely.

i. Collar, to give bearing to screw closing air-vent.

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f. Large screw cap for filling lamp, bearing on

w. Washer of leather or rubber.

o. Ring in front to which are attached chain to cap and chain to

t. Trimming needle.

h. Sheath of latter, lying between

k. False back, and

l. Main body of lamp, which contains the oil.

s. Socket between *k* and *l*, on which turns

b. A piece of stout brass wire, forming at the upper end a hook for attachment to the hat or projections of rock, etc. The plane of this hook is at right angles to the lower end of the wire, which forms a spike for driving into "dig," timbers, etc.

r. Collar on the upper part of *b*, to prevent vertical movement.

g. Cylindrical brass ring, attached to the upper end of

n. Conical copper spout.

d. Three small wire points inclined upwards to prevent the wick descending.

The writer used this lamp in its developing stages during the superintendence of several mines in Virginia, which were remote from each other. A preliminary note, written hastily before his departure for Europe, in October, 1881, was kindly interpreted and published by the Secretary of the Institute. Since then the lamp has been examined and favorably criticised by the writer's friends and former professors in the Mining School at Freiberg, Saxony, at which town a dozen were manufactured by one of the best tinsmiths and sent by freight to Philadelphia, in order to test the comparative cost of manufacture here and abroad.

The lamps made in Freiberg are light, weighing about seven ounces each. They are of copper fitted with brass.

M. Daubrée, member of the French Institute and director of the School of Mines in Paris, expressed also a favorable opinion of the lamp.

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ERRATA.

Page 460. In Figure 3 there should be inserted an O between M and N.
Page 469, 9th line from top, for *Black Tail* read *Blacktail*.
Page 470, 6th line from bottom, for *Terror* read *Golden Terra*.
Page 472, 6th line from top, for *Blocktail* read *Blacktail*; also on page 473, 13th line from bottom.
Page 472, 15th line from top, for *coping* read *capping*.

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